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CIVIL ENGINEERING.

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Abstract of a Report by Croizette Desnoyers upon that part of the Bourbonnais Railroad between St. Germain-des-Fossès and Roanne, a distance of 41 *miles.* Translated by J. BENNETT.

(Continued from page 15.)

TUNNELS.

THE Roanne branch has two tunnels, the Saint Martin d'Estréaux, 1504 yards long, and the Crozet, 247 yards; the first presented difficulties, owing to the hardness and want of solidity in the rock through which it pierced.

The Saint Martin d'Estréaux Tunnel.—Character of strata traversed.—The earth is classed among the red quartz bearing porphyries; at the site of the tunnel, there is a mass of very hard rocks, presenting, some distance from the head, a depression filled with hard gore or decomposed rock: the tunnel is established in this gore a length of 76 to 98 yards only, and the rest of the way it passes through rock, composed of red porphyry of porphyroidal granite, with great crystals of feldspar, and at certain points it passes into a sort of diorite with quartz veins; this rock encountered in shaft 7, and near the outlet of the tunnel, is the hardest of all. Its mass is not compact, and it may be regarded as a combination of huge blocks,

separated by their beds of clay or talc, in which, on making an opening, the blocks lose their equilibrium, sliding, falling, and producing enormous thrusts. To the great hardness and want of solidity of this portion, is attributed the difficulty of the work.

Mode of execution.—Works of this importance cannot at a simple inspection be made ready for contract, as the imperfect knowledge of what is to be met with affords no basis for proper plans. At first the shafts and gallery were entrusted to experienced contractors, who acted as overseers, the prices being regulated in parts and afterwards rectified as the advance of the work afforded the means of appreciating its value. After the completion of the gallery, all the principal elements of the work being known, the Orleans Company then took charge of it, and called for bids upon a well defined plan. The work, which was done by the job till the completion of the central gallery, was afterwards continued and finished upon a regular contract.

The mode of execution in the first period of the work, called for strict and detailed memoranda, and so afforded precise notes upon most of the results.

Shafts.—The excavations at the approaches were to be made after the tunnel was commenced, so that shafts had to be sunk at the presumed site of the two heads. Intermediate shafts were also indispensable on a distance of 1454 yards first contemplated,* to bring duration of work within reasonable bounds; their number was to be eight, spaced at intervals of 153 yards, except at the heads, which were 197 yards apart, as it was hoped that the approach excavations might be made in time to expedite the works at the ends. The depths of the shafts varied from 23·45 yards to 58·51 yards, and at a mean were 39·30 yards.

The shafts had an interior rectangular section of 4·92 yds. by 2·18 yds., and were divided into three compartments, two for the ascending and descending bins, and one, smaller than the others, for the ladders, pump, and ventilator. They were sheeted the whole height; this measure being indispensable from the frequency of landslides, the instability of the blocks, and the shocks from blasting. The pits were worked by horse-gins, which, with the openings of the pits, were covered by sheds, which sheltered the drainers and the discharging hands; afterwards, a fire-place was made at an angle of each shed, for drying the clothes of the miners. The openings of the compartments were formed of trap-doors, which opened only for the passage of the bins; this precaution prevented accidents.

The mean descent per week, varied from 1·66 yds. (shaft No. 2) to 0·92 yds. (shaft No. 7). The working of the last shaft, with a depth of 52·39 yds., lasted thirteen months.

The mean price per cubic yard of excavation, including drilling of holes, blasting, breaking up of material, raising, depositing, leveling, the finding of powder, lighting, repairs of tools, and fixtures, varied from $3·80 (shaft 2) to $9·85 (shaft 7): it was at a mean $6·31.

*Afterwards carried to 1504 yards.

These prices result from the memoranda, with the addition of ·05 for incidental expenses, and ·1 for profit.

For a zone of 7·63 yards in height, from the bottom of each shaft, the cost per cubic yard was more considerable, rising to $5·18 (shaft 8), and to $10·90 (shaft 7); as a mean it was $8·78.

Here is a table of the sub-details for the least and most hard of the shafts, and for the general mean.

Nature of Expenses.	Expense per cubic metre of excavation at the lowest part of each shaft.		
	Shaft 8.	Shaft 7.	Mean.
	francs.	francs.	francs.
Work of miners,	7·46	20·40	17·15
" laborers,	2·99	8·52	8·89
" horses and drivers,	2·66	8·19	5·54
Powder,	3·39	4·31	3·53
Lighting,	1·05	2·49	2·12
Different fixtures,	0·31	0·34	0·48
Repairing tools,	10·44	15·57	10·91
Fuses,	1·04	1·65	1·13
Gross,	29·34	61·77	49·75
·05 for incidental,	1·47	3·09	2·49
Net cost,	30·81	64·86	52·24
·1 for profit,	3·08	6·49	5·22
Contract price,	33·89	71·35	57·46

Note.—1 franc per cubic metre = 15·29 cents per cubic yard.

The cost of sheeting was $35·28 per yard of depth.

The cost of material for gins, bins, cars, temporary iron railways, cables, ladders, guys, sheds, &c., as paid to the supervisors, was at the rate of $1600 per shaft; but as during the construction of the tunnel this material was economized, we may set down $200 as the sum total for each shaft, or say $5·11 per linear yard.

We may set the cost of draining at $6·03 per yard.

According to these results, the net cost of shafts per linear metre was at a mean:

Excavation 16·6 cub. yds. at $6·31,	$105·47
Sheeting,	35·28
Cost of materials,	5·11
Drainage,	6·03
	$151·89

But in reality it rose to $182·80 per yard, since the price previously agreed upon with the overseers was found to be superior to those resulting to the valuation made during the prosecution of the work.

The Gallery.—The gallery was opened with a width of 4·15 yds., and a height of 4·59 yds., or 19 square yards. This section is greater than usually adopted, and the reason was that the miners required nearly the same price for from 12 to 14 yds. in section as for 19 13 yds. There was thus an advantage in adopting this dimension, which notably facilitated the work, without involving any serious inconvenience to the sheeting. But there would have been no advantage in having a larger section, for the experiment was made with one of 23·92 sq. yds., without sensibly diminishing the cost. The gallery was placed at the upper part of the appointed section, and it seems to be a good disposition, when the difficulty of working the upper part in hard rock is considered. The sheeting was dispensed with for about one-half the length; in the other half, they were not required to be very strong, though at some points, especially between shafts 9 and 10, the thrusts were so great that oak pieces, 12 inches square, were broken, and the frames had to be doubled and propped in the middle of their height.

The shafts were placed at 5·45 yds. outside the centre of the tunnel, so that before commencing upon the gallery, small cross-galleries had to be pierced, which have disappeared upon the opening of the tunnel section proper. Communication between pits and gallery was maintained by rail tracks; the trucks carrying the bins were received upon movable platforms, which did away with the need of turntables.

The mean progress of each gallery per week worked upon two faces varied from 4·69 yds. (gallery of shaft 2) to 1·39 yds. (gallery of shaft 7), and in the latter it took over eighteen months to establish a communication with the neighboring shafts; the mean progress of the whole gallery was, for each face, 1·46 yds.

As the faces worked were two for the intermediate and one for the end shafts, in all 18, we see that the general piercing advanced, as a mean, 26·28 yds. only, per week; that the mean volume taken out per week was $19{\cdot}13 \times 26{\cdot}28$, or 502 cub. yds.; and that the mean daily excavation was 72 cub. yds.

At each face there was a force of 5 miners, who worked for 10 hours, and were then relieved by another similar gang; in 100 hours about 3·92 cub. yds. were taken out. Each miner in 10 hours drilled nearly 3 holes, $15\frac{3}{4}$ ins. deep, so that each cub. yd. required 8 holes. The mean price per cub. yd., including the same manœuvring and equipments as the shafts, with the addition of incidentals and profit, varied from $3 63 (gallery of pit 2) to $12·62 (pit 7), and was at a mean $6·27.

As respects the hardness, the galleries may be divided into two classes: the first containing the galleries of the ends, corresponding to pits 1, 2, 8, 9, and 10; the second, with the central core, answering to pits 3, 4, 5, 6, and 7, in which the price attained the highest rate.

Here is a table of sub-details resulting from the valuation of expenses, which, being taken as a mean, have more value than extremes, which may present anomalies.

Nature of Expenses.	Cost per cubic metre in gallery.		
	Mean for galleries of shafts 1, 2, 8, 9, 10.	Mean for galleries of shafts 3, 4, 5, 6, 7.	General mean of shafts.
	francs.	francs.	francs.
Work of miners, . . .	9·10	21·24	15 17
" laborers, . . .	2·87	4·71	3 79
" horses and drivers, .	2·26	3·70	2·98
Furnishing powder, . . .	2·20	4·48	3·34
" fuse, . . .	1·03	2·10	1·56
Lighting, ...	1·11	2 29	1·70
Various fixtures, . . .	0·21	0·43	0·32
Repairs of tools, . . .	5·27	8 01	6·64
Gross cost, . .	24·05	46·96	35·50
·05 for incidental, . . .	1·20	2·35	1·78
Net cost, . .	25·25	49·31	37·28
·1 for profit, ...	2·53	4·93	3·73
Contract price, .	27·78	54·24	41·01

Note.—1 franc per cubic metre = 15·29 cents per cubic yard.

The mean cost of galleries (41·01 francs), or $6·27 per yard, is nearly the same as that of the shafts (41·29 francs), or $6·31 per cubic yard; but, in reality, it is only with the lower portion of the shafts that the comparison should be made; now the price for this lower part is $7·78 per cubic yard, and, consequently, the gallery excavation has cost ·714 of that of the corresponding part of the pits.

The above table enables us to reckon the number of days, the quantity of powder, of fuse, the number of points of tools, and all the principal elements of work per cubic yard.

Thus, the wages of miners being 90 cents, we see that 3·37 days per cubic metre, or 2·58 days, were required per cubic yard.

The price of powder being 2·25 francs the kilogramme (20·4 cents the lb.) the quantity per cubic metre was at a mean, 2·52 lbs. per cubic yard, and as we have seen that there were eight holes per cubic yard (10, per cubic metre), it follows that the charge for each hole was 0·33 lb. The miners generally reckoned 2·2 lbs. for 7 blasts.

At the rate of 1·83 cents per yard (0·10 francs the metre) the length of fuse was 13 yards per cubic yard, say 1·61 yards per hole.

The repairs of tools consisted mainly of re-pointing the drills; each point costing 2 cents; there were required 50 per cubic yard (66 per cubic metre), or 7 for each hole. But in the hardest galleries the quantity was greater; thus, for shaft 7 there were used 15 points per hole,

and, especially at the commencement, after a few strokes the drill would get dull and have to be replaced.

Referring to a period of 24 hours for the different elements of work for the whole tunnel, we find for an advance of 3·75 yards, and consequently for the excavation of 72 cubic yards, there were required 180 days of miners, 181 lbs. of powder, 90·5 yards of fuse, and 4000 points of drills.

For delivery and loading excavation, raising in bins, and depositing it, there was required 1·14 days of laborers per cubic yard (1·5 per cubic metre) and 0·37 days of horses, or say in 24 hours for the whole tunnel 82 days work of laborers and 27 of horses. For the period of 24 hours, answering to 20 hours of effective labor, 3 horses were used for most of the shafts, and two only for those which yielded the least. The horses were very strong, since the loads raised were heavy; but they rested often, since the quantity per day was small, and this sufficiently accounts for not using a steam engine.

The cost of drainage was at a mean $36·00 per day, and $9·69 per yard of gallery.

The expense of material may be set at $4·02 per running yard.

The cost of sheeting the galleries was $12·24 per linear yard for the whole tunnel, and $24·31 for the parts actually requiring it.

From these results the actual net cost per linear yard should be, as a mean:

Excavation 19·13 cubic yards at $6·27,	$119·94
Sheeting,	12·24
Draining,	9·69
Materials,	4·02
Total,	$145·89

The cost was greater, in fact, because for a length of 240 yards the section of the gallery was 23·92 yards, and because the overseers had at first too high a price, which was afterwards rectified when a more exact basis was attained

Upper breastwork.—On the completion of the gallery the upper section of the breast (the bottom of which was at the same level with that of gallery) was commenced. In the most solid parts there was no sheeting and for remainder of tunnel, sometimes it was sufficient to support a part of the crown; then again the whole surface had to be supported by fan-shaped struts covered with joists. Care was taken to have it well sheeted in all parts and wherever the ground was not of undoubted solidity the breastwork was carried on by short advances just enough to provide room for the masonry constructed immediately after the excavation.

For the first part of the work regular notes were taken, showing the cost as $4·40 per cubic yard. After trials proved that this price agreed well with the general mean.

The section varied from 10·75 to 16·75 square yards, according to the thickness of the lining, and at a mean stood at 13·75 yards.

The expense of sheeting is not given as it fell within the regular

contract of the second period, as the same planks served for a great number of rings, and as the arrangement of the struts was so variable that their contents could not be appreciated. It is s mply stated that the expense was inconsiderable, that the work was made with sheeting of the gallery, and so required no new equipment.

Lower breast section.—The remaining section of the tunnel (called *strauss*) was mostly excavated after the construction of the arch. It was only in the solid portions that the entire section could be safely opened before the lining of the arch, and it is perhaps best in no case to do it, even though there were no concussions or injuries to be apprehended from the blastings. These evils were much less than anticipated; by covering the blasts with fagots the fragments of rock were sufficiently kept from the arches, and there were but few exceptions where the bricks were injured or had to be replaced.

The excavation of the lower section was valued at $4·18 in the hardest part of the tunnel, and at $2·80 in the other part, and at $3·49 at a mean. Experiments made during the construction have shown that the cost should not have exceeded $2·75 per yard.

The section (strauss) to which this price refers, varied from 28·75 to 32·7 square yards, according as the piers were or were not lined, and as a mean was 30·75 square yards.

Thus the cost of excavation of the shaft $7·78 was reduced to $6·27 for the header, $4·40 for the upper, and $2·75 for the lower breast; which, reckoning the surface of each part of the tunnel, gives $4·29 for the mean cost of the whole section. The general section varies from 56 to 64 yards, with some exceptions. The mean section amounts to 61 yards.

Arches.—The interior section of the tunnel is a portion of an ellipse with its centre 6·43 feet above the base (answering to 4·26 feet above the rails), and whose semi-axes are respectively 15·08 and 12·63 feet. With these dimensions the width at the level of the rails is 24·27 and the height above the exterior rail is 15·74 feet. Upon the continuous elliptic surface, the arch answers to that part situated 13·12 feet each side of the key, having thus a development of 26·24 feet. This portion was constructed either of bricks or rubble masonry. All the remainder, regarded as piers, was made of rough rubble obtained from the excavation.

The thickness of the arch is quite variable. According to the plan the arch was to have been entirely constructed of brick, with a thickness of 1·15 feet or 1½ bricks for one section, and 1·97 feet or 2½ bricks for the other. But on constructing, it became necessary to increase the thickness at points of great pressure, and in some cases to substitute granite rubble for the brick; on the other hand, in the solid parts the lining was of no other use but to keep the rock from the action of the air, and might be reduced to the simple length of a brick or 9 ins.; the normal sections have thus conformed to Figs. 3 and 4, Plate II, saving that sometimes intermediate thicknesses of 1½ or 2 bricks have been adopted, and sometimes in the heaviest loaded portions, rubble work with well dressed beds has been laid in thicknesses varying from

2·3 to 3·3 feet. The mean thickness is about that of the plan 1·56 feet; while the dimensions at the different points conformed to the necessities of the case revealed by experience.

In the solid parts where the arch was constructed after the excavation of the lower breast, the centres were easily moved on rollers, which could not be done in the upper breast on account of the uneven level at the bottom of the header.

The arch was constructed at a maximum in lengths of 13 ft., being reduced in difficult parts at least to 6½ ft.

Piers.—The part of the piers between the bottom of the gallery and the arch proper, was constructed at the same time with the arch. On making the plan, there was a hope of dispensing with the construction of piers upon one-half the tunnel; but it was impossible, at least for the part above base of header, on account of the difficulty of cutting the rock, so as to be a prolongation of the curve of the arch.

The same difficulty was found in cutting the batter of the lower section, both from the interior rents caused by the blasts, and because the upper surface was too inclined to support the masonry in safety. So that, in reality, although the rock was solid enough to require no lining for over a half of the length, yet it was not dispensed with for more than a quarter.

The underpinning was executed in lengths of from 6·5 to 13 feet. When the earth was quite solid, strutting was not used; when of a medium solidity, the masonry already built was shored, and a simple inclined brace put up; when of an inferior solidity, a thorough system of strutting was adopted, and sometimes shores were placed between the principal brace and the abutment of the opposite side.

Gutters and Aqueduct.—At the level of the springing of the arch, throughout the length of the tunnel, small gutters were made, with alternate slopes, abutting at intervals of 164 feet upon cement pipes, which conveyed the water to the central aqueduct, made in the middle of base of tunnel. This aqueduct, besides the water from these pipes, received that of the bottom, from the small outlets prepared for that purpose.

Closing of shafts.—There were four shafts, Nos. 3, 5, 6, and 8, retained for the ventilation of the tunnel. Their distance apart at the centre was 152½ yards, but was increased towards the heads. They were lined with masonry of an elliptic section, Figs. 5, 6, and 7, Plate II.; but as the masonry occupied but a portion of the void which had to be filled, it was strengthened by a buttress alongside of filling. The bottom of the shafts served as sidings for track repairers. Other sidings were reserved at intervals of 76 yards throughout the tunnel.

For the suppressed shafts, a filling of the whole height would probably have thrust out the abutment of the arch; there was therefore made at the base, two small discharge arches, which were filled with rubble, and covered to a certain height with rubble, which supported the upper filling; the water drainage was carefully provided for, and a siding left at the bottom.

The heads of the tunnel are very simple, supporting a tablet giving

the length, height, and dates of construction. That on the Saint Germain side is of beautiful gray granite, and that on the Roanne is of Chevroche limestone. In the latter, the counterforts resist the great exterior thrust, and serve to amend the unpleasing effect arising from the different inclinations of the slopes of the excavation.

General expense.—

The expenditure during the first period of the works for shafts, galleries, and the commencement of breast, was . .	$332,493 00
The completion of the work was contracted for at the rate of $241·29·6 per running yard for 1476·36 yds. of length first adopted,	356,400 00
But as the tunnel was lengthened 32·81 yds., there is an addition at the rate of $365·60 per yard, . . .	12,000 00
Finally, the cost of contingencies for supervision and for various fixtures, amounts to . . .	18,000 00
	$718,893 00

Or, in round numbers, for a length of 1509 yards, $476 per linear yard.

The shafts and heads appear in the expenses with the sum total of $74,000, or $50·35 per linear yard. The net cost of the tunnel proper may be thus set at $426 per running yard.

A careful study of the work proved that, notwithstanding the real difficulties of execution, this price was too high by about $36·56, due to the two above-named causes.

At first, the mode employed for the construction of the shafts and header caused the overseers to undertake the work at a high profit, and it was for their interest that the results of the valuation, as data for the contract, should reach as high a figure as possible. The first period of the work has, therefore, cost too much.

In the second place, the negotiations between the state and company for the transfer of the work, occasioned the loss of five or six precious months in the season of 1855, and the consequence was, that between the tenders made (one at the commencement of negotiations, the other at the end,) by the contractors, there was a difference of $21·93 per linear yard.

The engineer here submits a table of what he considers to be a fair price for a tunnel in similar conditions with the Saint Martin. Without giving the details, the general cost per linear yard of full section for very hard and solid porphyretic rock, of the type of (Fig. 3, Plate II.) was $402·16; for hard, but not solid, porphyretic rock, type of (Fig. 4, Plate II.) was $393.

The expense does not differ much, because the increased masonry compensates very nearly in the second case for the decrease of hardness in rock.

Supposing that the shafts were of the same depth and in the same conditions as at St. Martin, the total cost per yard would be $438·72.

Time of execution.—The first shaft was commenced in November, 1852, and the others shortly afterwards, so that they were finished at

nearly the same time; the first part of the work lasted a year. The driving the headers lasted another year, excepting that of shaft 7, which required more time, but did not prevent the breastwork and masonry upon the remainder of the length. At this time (Feb., 1855), the tunnel was to have been put out at contract in behalf of the state, but the negotiations with the company prevented this measure, and up to the month of the following July, nothing was done. The works were then let by the company, July 6, 1855, and since then were conducted with great activity. This last period, including the construction of arches, the underpinning of piers, and accessory works, lasted two years; so that, in reality, the locomotives passed through the tunnel in November, 1857, five years after the commencement of the first shaft, but with four years and a half only of effective work.

According with the basis of a mean progress of 4·39 feet per week upon each face, if the tunnel had been worked solely from the heads, it would have taken ten years, on the supposition that the cuts were previously made. In consideration of this fact, the dispositions adopted at the beginning of the work should not be regretted.

Accidents during the construction; landslide between shafts 8 *and* 9.—Some time after the opening of the gallery between shafts 8 and 9, in a portion which seemed solid, and which therefore had not been sheeted, a serious slip occurred. It extended in length about 44 yards, and in height 26 feet above top of gallery. In the upper part, the direction of the void was oblique. The surfaces were very smooth, and covered with a light bed of clay; the position of the faults, and the presence of this clay, occasioned the sliding of the blocks, which were of enormous size, having in some cases tables of porphyry 8·74 yds. by 9·84 yds. by 1·53 yds., containing 131 cubic yards. To prevent the spread of this movement, the gallery was hastily and strongly sheeted at the ends of the slide, and in the slide itself braces were placed, sustaining many parts of rocks whose fall was imminent.

The repair was a difficult matter, for a portion of the rocks remaining in place was full of fissures; others appeared on the verge of sliding, and were only held up by the sliding mass. There were fears in taking away these blocks of creating fresh movement in the upper part; the blocks, on account of their size and hardness, could not be taken away except when divided by blasting, and the resulting shocks might detach new portions of the rock, and aggravate the evil. In this dilemma, recourse was had to the following method, proposed by M. Simon Trône, one of the contractors for the second period of the work, which was executed by him with true skill.

A commencement was made in circumscribing the landslide, by pushing forward as far as possible on both sides, the construction of the arches, so that, before attacking the slide proper, the length between the constructed arch was reduced to 30 yards. If the attempt had been made to directly re-establish the gallery by attacking the lower part of the slide, even with the help of strong sheeting, it is quite likely that the whole mass, as well as a great part of the rock then in place, would have been precipitated. They therefore sought to effect

a way through the upper part, dividing it by slight blastings, and by carefully taking away in parts the blocks forming the summit of the slide; so that a slight advance being made, a wooden frame conforming with the void was hastily erected, and strongly supported upon this were stringers sustaining the rock, which were urged forward as far as possible, when the excavation began for the raising of another frame, and so on till the date of April 25, 1856, when the consolidation of the upper part, and a communication above the slide was effected between the two portions of the gallery on either side of it.

From this time confidence was restored, and the second period of repair closed with the removal of the lower part of the fallen mass, and the construction of the masonry. Passing over the details, suffice it to say, that the arch was made of granite rubble, with well dressed beds; that a thickness of 3 feet was given to the masonry, and care was taken to fill the upper void of the slide with dry masonry laid as close as possible; and at the closing of the last ring, a discharging arch was thrown over the dry masonry, in which a man could work till the last moment, and which served for as solid a filling in as that given to the adjoining rings.

The work of passing through the slide lasted over six months.

At different periods of the construction of the tunnel, especially upon the breastwork, there were several other slides, but of less importance than that just described.

Slide between shafts 9 *and* 10.—In the underpinning for the construction of the piers, an accident of another kind occurred between shafts 9 and 10, worthy of notice. In this part, the rock formed a compact mass on one side of the tunnel, but on the other presented numerous faults filled with clay; these faults were nearly parallel, and much inclined towards the centre of the tunnel. The arch had been constructed carefully and completed without accident; but in resuming the underpinning, after having constructed several lengths of piers, too many of the intervals were worked at one time, and a movement took place, which thrust the arch inwards; some of the voussoirs were broken, but the arch did not fall and continued to present a regular curve. At the origin of the slide, the displacement at the springing line was very little, attained 16 ins. about half way, was 8 ins. at five-sixths, and ended a few yards beyond this. The portions of piers already constructed were pushed inwards the same as the arch. This movement extended 38 yards.

They commenced by replacing the arch upon its centre at the two ends, and by an immediate reconstruction of the altered part, wherever the pier had not been worked. In the part already excavated, the deformed side of the arch was strongly shored against the sound side of same, and braces being put under the projecting angle, the pier was constructed in its true position. The parts of the neighboring piers which had been moved were also rebuilt; then the displaced portion of the arch was demolished, and rebuilt in its true place. Portions of inverted arches were also constructed to prevent any future movement of the piers. After the repairs not the slightest movement has been detected.

The Crozet Tunnel.—The Crozet tunnel pierces a spur near the Pacaudière, and its summit is 31½ yards above the road bed. The ground traversed presents in the centre a core of granite, covered on either side by a mass of hard gore. The tunnel being but 247·4 yds. long, was worked from the two heads, and this, with the difference of hardness, rendered the execution much less expensive than the St. Martin d'Estréaux tunnel.

The interior section is the same as the St. Martin; but the lining is complete for the whole length, even for the piers, and the thickness of masonry is greater; the arrangement of the gallery and the mode of sheeting are the same. Owing to the inconsiderable depth of earth, its character was easily ascertained by soundings, which cost about $2·19 per linear yd., for soft and hard gore, until it struck the rock.

Expense.—There were two prices, one for granite, the other for common earth. Passing by the details, the general price per linear yard (full section) in granite, was $288·82; for common earth, $200·71: as a mean, $244·76.

Observations made during the work show that the estimate was sufficient for the portion in rock, but not so for that in earth, and that the mean price should have been $254·92.

On comparing the price of the rock part of the Crozet tunnel with the least hard half of the St. Martin, we are struck with the difference $288 and $393, for the hardness was about the same in each. This difference arises mostly from the different modes of working, one from the heads, the other through shafts. The cost of raising the excavation at St. Martin caused an increase of from 46 to 61 cts. per cubic yard, or say from $27 to $36½ per linear yard of the whole section. The masonry of St. Martin made an increase of $16 51, or ·2 of the expense, due to the passage of materials through the shaft. The cost of drainage was, of course, much less at Crozet, since, during the greater part of the work, the water was passed through at the heads without special provision for it. The difference in the mode of working has diminished the net cost from $81 to $91; if to this we add the suppression of the shafts, say $45¾, we see that the same tunnel which, constructed by shafts at a cost of $438 per yard, would not cost over from $310 to $329, if the whole had been worked from the heads. This is a grave consideration, which, though disregarded when pressed for time, should yet prompt us on works of long duration to begin early with tunnels of a certain extent, so as to realize a saving of one-quarter the expense.

	For very hard and solid porphyretic rocks, type fig. 0.	For hard porphyry but not solid, type fig. 0.
Cost per cubic yard.—Gallery,	$8·25	$4·28
Upper breast,	5·50	3·06
Lower "	3·36	2·14
Brick masonry,	7·64	7·64
Rubble "	5 35	5·35
Dry Stone "	3·06	3·06

Retaining walls at Crozet.—Just before arriving at the Pacaudière station, the railroad cuts the foot of a steep hill, upon the summit of

which stands an old tower, and a great number of houses, forming the village of Crozet. The usual slope of 45°, would extend throughout the whole height of the hill, and tend to undermine the foundations of the tower. Moreover, on the upper part, were some boulders, while on the lower part of the hill, that to be excavated, was a clayey gore of bad quality. Some mode of consolidation had to be devised, and a prompt one, to guard safely against the fall of the tower and houses. A retaining wall was planned; only instead of giving it a uniform thickness, it was composed of circular parts, 19·7 feet long, stayed by counterforts 6½ feet thick. The earth at the upper part was to have been cut along the line M N, Fig. 8, Plate II.; but in the course of the execution, numerous slides occurred, causing great difficulty in the foundations of the walls, and some alarm for the preservation of the houses on the hill, so that the final slope took the form indicated by the broken line O P Q N: the space between the slope and wall was filled with rubble, and this consolidation sufficed to arrest all movement, without the necessity of resuming the projected slope along M N.

The thickness of a wall should be proportionate to the difficulties of its position and the chance of damage from accidents; but aside of this, the adopted arrangement is thought preferable to a wall with a uniform profile; first, because that one of the components of thrust produced upon each intermediate portion is destroyed at the axis of the counterfort, by the similar component of the adjoining section; and, secondly, because the counterforts present solid supports, and in case of accident prevent the movement from spreading, as with walls of a constant thickness. It is thought that a given volume of masonry can be more usefully employed with this form than with that usually adopted.

Water passages of the Sigaud's bridge.—It is often useful for the settlement of damages, to preserve for proprietors their water rights on either side of the road. When cast iron bridges are constructed over a cutting, the preservation of water passages may be had with but little increased cost, by using beams of a rectangular section, conformably to that given in Fig. 9, Plate II., for a bridge 41 feet span. To clean out the small channels thus formed, longitudinal openings, like those shown upon the plan, Fig. 10, Plate II., are made in the top of the beams, through which is introduced a small spade, which by turning round at right angles may clear the whole section of the beam.

Culverts 6½ feet span.—Culverts of 6½ ft. span were constructed under banks from 65 to 82 ft. high, and it was important to give them a form best fitted to resist this great load. An elliptic section was accordingly adopted, Figs. 11 and 12, Plate II. When the foundation has but little depth, the bottom of the ellipse is intersected by an inverted arch; but when it is deep, the ellipse is complete, except when a false invert is made for the passage of men or cattle. The two sections of these culverts, with the dimensions adopted in building, are given, because there is a general scarcity of types of such works

under great embankments, and because, at the same time, if experience has proved that the dimensions adopted upon their line were sufficient for solidity, it has also shown that these were not far from the limit, and that the want of proper precautions has occasioned many accidents.

Instead of constructing the culverts in the lowest part of the valley where the solid earth has usually a great depth, great care was taken to place them upon the side, as shown in Fig. 13, Plate II. By this, expensive foundations were avoided, the length between the heads reduced, and in undulating ground, the water did not become stagnant above, when advantage was taken of the difference of slope existing between the upper and lower footing of a high bank, which always has a wide base.

The culvert being constructed, great precautions are to be taken with the covering of the bank, to avoid any displacement. On this account the dumping should be stopped a little in front of the culvert, the earth to be taken in barrows, and laid on in thin well rammed layers, first upon the lowest side, and then upon the other, so as to envelope the culvert with a mass of earth indicated by the dotted line, *a b c*. When the bank has reached a height of several yards, then it may be advanced by dumping the earth from its summit. This precaution was not always sufficient; for three culverts, which had been covered by barrows a height of from 23 to 26 feet, experienced a slight displacement, manifested in the opening of some joints; another culvert, the Bertalière, which had a cover of 10 feet of earth, whose masonry had been constructed in a far advanced season, was deformed in the arch, and the masonry in the upper part was displaced from 3 to 4 inches.

Another kind of movement was produced in the Closdit culvert, but more difficult of explanation; it was found separated in two parts at the middle, by a section a little oblique to the axis. The separation might have been easily explained by a settlement, had not the two parts been found to be at the same level; but the least difference in height could not be detected, nor the least departure from a true range, either in the arch or invert. As the rupture is nearly at the centre of the culvert, it is probable that the weight of the bank caused the middle to settle more than the ends, and may thus have caused the disjunction, though the curve which the key in this case would naturally take from head to head was wholly imperceptible.

Accident at the Roudillon Bridge.—A more serious accident occurred during the construction of the Roudillon bridge. This work, of the type most frequently used in excavation, is formed by an elliptic curve 40·8 ft. span, 11·5 ft. rise, resting upon abutments 5¼ ft. high. The heads are of cut stone granite, and the intrados of rubble granite blocks, with 1·1 ft. tailing. In taking down the centering, the heads settled from ·6 to ·8 in., and the joints at the extrados slightly opened at *a b c*, *a′ b′ c′*, Fig. 14, Plate II. This movement, though too much for an arch of this span, did not excite any alarm; but it was much greater at the rubble intrados, which at the centre was lowered from

3 to 4 inches, and thrust outwards the bottom of the head voussoirs ·8 inch; in this movement the voussoirs were detached from the rough rubble, which completed the thickness of the arch, leaving an interval of 1·6 inches; at the same time the joints were opened upon the upper surface, a necessary consequence of the thrust exerted upon the heads, and the displacement produced by it.

The arch was entirely torn down, and rebuilt. The contractor laid the accident to a want of sufficient height in the spandrils, to resist the thrust to be expected in the taking down of centering. This may explain the unusual settling of the heads, but not the difference existing between it and the rubble blocks. The accident is really due, 1st, to the too great uniformity in length of tailing of the blocks; 2d, to bad masonry and insufficient care in bonding the intrados blocks with the coarse rubble upon it; 3d, to bad mortar, made of a somewhat earthy sand; 4th, to inequalities, and too much haste in uncentering.

This accident again proves, that the construction of all these works, even of current dimensions, demands a careful watch at all times. It shows particularly how important it is in the construction of arches, to bond the intrados stones with the masonry forming the complement of the thickness of the key.

Iron Hand-railings.—Upon most of the works, with the exception of the great viaducts, a hand-railing, represented in Figs. 15 and 16, Plate II., was used. The uprights and rails were of T iron, which with small weight presents great resistance in both directions. The cross-bars are flat, and are riveted to each other and to the principal pieces. The railing of this type weighs, according to the distance of the posts, 36 to 40 lbs. per lineal yard, or nearly one-half of the common railing in full iron. The price varies from 9 to 11 cts. per lb., so that the mean cost per yard is $3·84. It has a pleasing effect upon the eye, and is cheap.

The bridges, culverts, and aqueducts are in number,	123
" over the tracks	17
" under "	16
Their cost per mile—1st section,	$7,264
2d "	16,718
3d "	6,297
Mean cost per mile,	$10,093

Summary of Expenses.

Mean cost per mile.	
General expenses,	$2,442
Purchase of land,	8,549
Earthworks and accessories,	35,092
Roads and drift-ways,	1,841
Great works of art,	30,121
Various works of art,	10,663
Stations,	4,005
Guard houses, &c.,	1,074
Total,	$93,787
The estimated cost was	$3,800,000
The actual "	3,840,000

I am indebted to John Houston, Esq., Engineer of Bergen Tunnel, for the following account:

Engineer's Office, Bergen Tunnel, 1st December, 1860.

JOSEPH BENNETT, ESQ.

Dear Sir:—Bergen Tunnel was commenced in 1855, and prosecuted for some eighteen months, when the work was suspended on account of financial difficulties, and was not resumed until February, 1859, at which time I first became engaged on it. Before the work suspended, all the shafts (eight in number) had been sunk, the heading, with the exception of 168 feet, had been driven, and about 900 feet of the bottom taken out.

The tunnel is 4200 feet long, and has a sectional area of 580 feet, or about 21½ cubic yards per lineal foot. The extreme height is 23 feet, extreme width 28 feet. As there was such a small amount of heading to drive after I became connected with the work, and as that was in detached pieces, I had not much opportunity to find out the accurate cost; but the following figures may be relied on as nearly correct. The amount taken out as heading was four cubic yards per lineal foot, and our gangs drove about one foot per day of 24 hours. The expense in the 24 hours was as follows:

24 miners at $1·37½,	=	$33·00
2 foremen at $2·00,	=	4·00
4 laborers at $1·12½,	=	4·50
2 tool-boys at 75 cents,	=	1·50
½ keg powder at $3·75,	=	1·87½
50 feet fuse at $4 per M,	=	·20
Lights,	=	·50
Steel, say 5 lbs. at 15c.	=	·75
Expenses per day,		$46·32½
4 cubic yards at $11·58,	=	$46·32
Cost of heading per cubic yard,		$11·58

The bottom or breast-work in the shafts, which were worked to the best advantage, cost as follows:

Expenses under ground on one breast, each 24 hours.

30 miners at $1·25,	=	$37·50
14 laborers at $1·12½,	=	15·75
2 foremen at $2·00,	=	4·00
2 blacksmiths at $1·37½,	=	2·75
2 helpers at $1·00,	=	2·00
2 tool-boys at 75c.,	=	1·50
2 kegs powder at $3 75,	=	7·00
100 feet fuse at $4·00 per M.,	=	·40
25 lbs. steel at 15c.,	=	3·75
1½ gallons oil for light at 60c.,	=	·90
		$75·55

Expenses on top for 24 hours.

4 top-men at $1·00,	=	$4·00
2 engineers at $1·50,	=	3·00
2 firemen at $1·00,	=	2·00
Oil,		·20
Coal for engine and blacksmiths, nearly 2 tons at $5, say,		9·00
		$18 20

Working Piers.

Fig. 1.

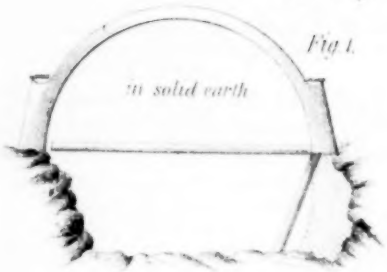
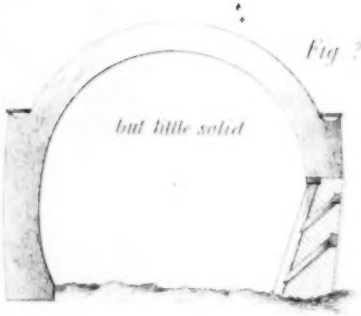


Fig. 2.



Vertical Section through Axis of Shaft

Fig. 5.

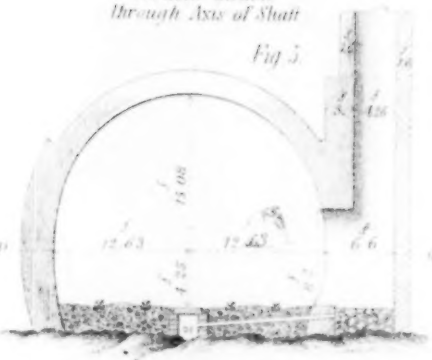
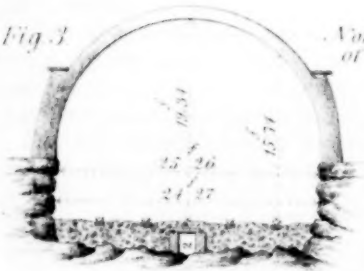
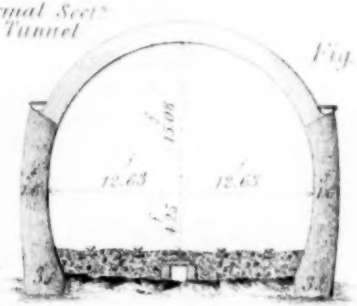


Fig. 3



Normal Sect.ⁿ of Tunnel

Fig. 4



Sect.ⁿ on top

Fig. 6.

hor.l sect.ⁿ along PQ

Fig. 7.

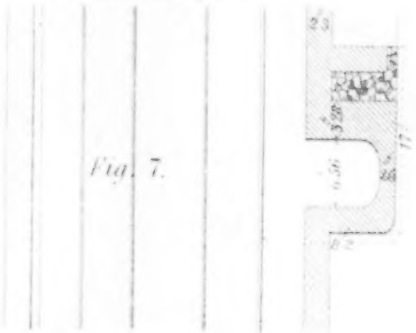


Fig. 8.

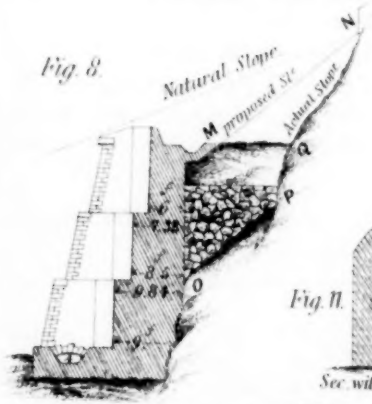


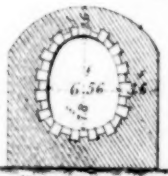
Fig. 9.

H
Cast Iron Bridge

Fig. 10.

Plan of Beam

Fig. 11.



Sec. with small depth of found.ⁿ

Fig. 12.

Sect.ⁿ with deep found.ⁿ

Fig. 13.

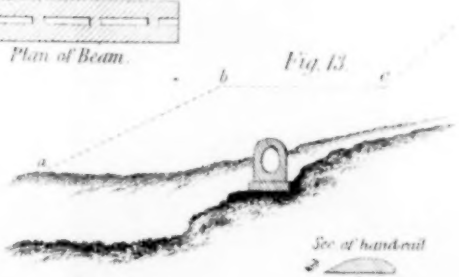
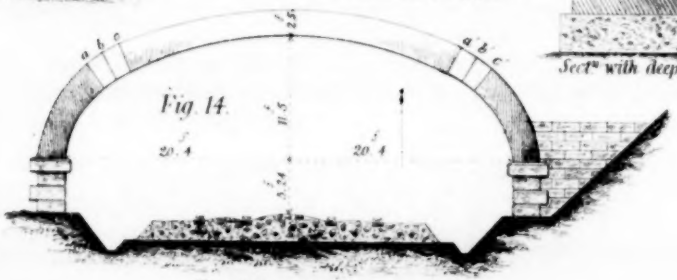


Fig. 14.

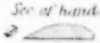


Roudillon Viaduct.

Fig. 15.

Panel of Hand-rail.

Sec.ⁿ of hand-rail



Cross bars

Fig. 16.

Uprights & rails

Amount brought forward, . . .	$75·55
Add one-half of this expense ($18·20) to the under-ground expenses on one breast, . . .	9·20
Total expenses for one breast in 24 hours, . .	$84·75
Average number of days worked per month,	23.
23 days at $84·75, . . =	$1949·25 per month.

The amount taken out as bottom was 17·5 cubic yards per lineal foot, and the average number of feet worked per month was 27 on one breast, making 472·5 cubic yards per month.

472·5 cubic yards at $4·12½ . . =	$1949·06
Expense per month, as above, . . . =	$1949·25
Cost per cubic yard, ...	$4·12½

To this cost it would be safe to add 12½ cents per yard, for tools, &c., and for trimming the sides and bottom before laying the permanent tracks.

With regard to the expense of sinking the shafts, I can say nothing further than that from all I can learn, those of the Bergen Tunnel being large (16 × 20) and generally dry, did not differ much per yard from the cost of the heading. They are from 80 to 90 feet deep.

The rock through which the tunnel is bored is basaltic trap, and said by miners to be a good rock to work, blasting well, though hard to drill.

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*Observations on the Niagara Bridge.** By PETER W. BARLOW, Esq., C.E., F.R.S., F.G.S., &c., &c.

(Continued from page 22.)

On the Mechanism of Bridge Construction.

In the following table is given the weight of metal, deflection, and ratio of ultimate strength to strain by weight of bridge, in the Niagara Bridge, and in those of the longest girders:

Name of Bridge.	Depth.	Span.	Weight.	Deflection.	Ratio of Strength to Strain by Weight of Bridge.
	ft.	ft.	tons.	tons.	
Niagara, . .	59	820	{ cables, 400 / wood, 600 }	0·82 ft. with 326	6·5 to 1
Britannia, . .	30	460	1550 tons.	2 in. with 248	3·4 to 1
Conway, . .	24	400	1150 "	0·69 in. with 100	3·8 to 1
*Saltash, . .	54	450	1100 "	1·17 in. with 384	5·0 to 1

* See Report of Col. Yolland, in the Appendix.

My object is now to endeavor to explain why these differences are consistent with understood mechanical laws, and the peculiar properties of the material employed.

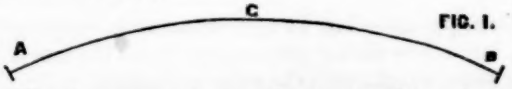


FIG. 1.

Let A B C, Fig. 1, represent an arch supported on abutments, A and

* From the London Engineer, No. 253.

B; and let the deflection produced by a given weight, loaded equally, be represented by unity.

Now, let us consider the effect of making this arch into a self-supporting structure, or bow-string girder, by removing the abutments and substituting a tie, A B, Fig. 2.

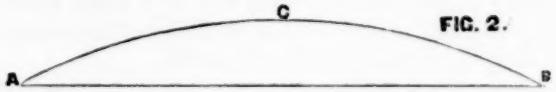


FIG. 2.

Assuming the same weight, W, to be placed equally all over, the deflection will be 2, the points A and B being no longer rigid, because the tie, A B, will extend as much as the arch, A C B, will compress. Therefore, to produce the same rigidity in a bow-string girder, four times the metal is required as compared with an arch.

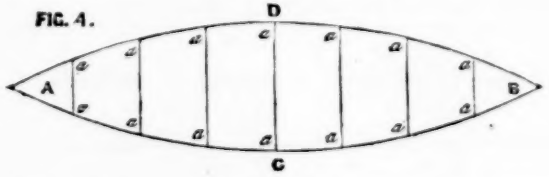
The same result arises in a cable, A C B, suspended from two fixed points, A and B, Fig. 3.

FIG. 3.

If the back chains are removed, and a compression-tube, A B, substituted, the metal is doubled, and you have a structure with only half the rigidity. The Chepstow Bridge, on the South Wales Railway, is an example of this arrangement.

The mechanical combination in the Saltash Bridge is represented by substituting the arch, A D B, for the tie, A B, Fig. 4, forming a combination of a suspension chain and an arch.

FIG. 4.



The arch, A D C, will not perform the duty of compression unless it is connected with the chains by the ties, *a a*, *a a*. When thus connected, both the cables and the arch assist in supporting the weight of the load.

The points A and B now become fixed points, and, as both the arch and the chains assist in supporting the weight, the deflection will only be half that of the simple suspension-cable, with double the weight of metal.

It therefore appears—1st, To convert an arch, supported on two fixed abutments, into a bow-string girder, four times the metal is required to support the same weight with the same deflection.

2d, To convert a cable, suspended from two fixed points, into a Chep-

stow girder, four times the metal is also required to support the same weight with the same deflection.

3d, To convert the same cable into a Saltash combination, (which consists of a bow-string and Chepstow girder combined, so that their horizontal tie in one case neutralizes the compression-tube in the other, by which they are both avoided,) the deflection is reduced one-half, with double the weight of material, or the same weight of metal will produce the same deflection with the same load, as in the case of the simple arch or cable. But this is obtained at the expense of double the depth; and if the arch or suspension-cable was of the same depth as the Saltash, only one-quarter of the metal would produce the same stiffness.

In the preceding illustration the bow-string and Saltash girders are referred to: parallel girders are more commonly used, but they present no economy over the simple bow-string; and, however perfect their arrangement and proportions, they will still require not less than four times the metal of a simple cable of the same depth and span to produce the same deflection.

Theoretically the same saving will be produced by an arch, but practically it does not hold good in large spans, because of the difficulty previously referred to of dealing with severe compression, and which difficulty applies also to deep girders. You are never certain of the section of metal required on a large scale, as by no calculation can the point be arrived at with certainty when distortion will commence, and thus the section of metal adopted is greater than would be required if the simple compression resistance had alone to be contended with.

The same objection does not apply to the suspension bridge, and as the resistance to tension alone has to be contended with, it may be known precisely what will be the ultimate strength of your structure; and hence arises another source of economy on this principle, in excess of the saving of one-fourth above described.

There is a third source of economy in suspension bridges which has to be noticed, namely, that iron intended for tensile strains admits of a process of manufacture by which a much greater power of resistance per square inch may be given to it than can be accomplished in iron intended for compression, which is proved by all experiments on iron wire, which exhibits a tensile resistance double of any metal used for compression strains.

These practical reasons, in addition to the mechanical laws previously described, when examined in detail, fully demonstrate the reason of the degree of strength obtained in suspension bridges with a weight of metal so small as compared with that of parallel girders of less span; and the only question of doubt, with reference to the advisability of this construction, is the possibility of curing the undulation and vibration which have generally been observed; and it is to this subject that my experiments, laid before the British Association, were directed.

On the Cure of the Undulation of Suspension Bridges.

A suspension cable or chain has so evidently no power to resist a

transverse strain, and a large wave or undulation is so readily produced by a vertical force, in bridges of small span and weight, that it is surprising that a suspension bridge was ever designed without giving longitudinal stiffness to the platform of the roadway.

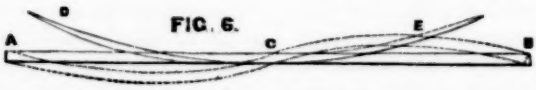
It has been assumed that the degree of longitudinal strength, or girder power, to cure the wave from railway traffic, would require to be so great that the girder would carry the traffic without the cable, and thus the failure of the Niagara Bridge was predicted; but a brief consideration of the subject satisfied me that such an assumption was far from the truth.

The formula $\frac{l^3 w}{b d^3 \delta}$ = a constant quantity, δ denoting the deflection, and l, b, d, the length, breadth, and depth of a beam is fully established; or, in other words, the deflection of a beam with a given weight diminishing as the cube of the length.

Fig. 5.

If the beam, A B, Fig. 5, be divided into two beams by being supported at C, the two half beams, A C and B C, will deflect one-eighth of the amount of the entire beam, A B, with the same weight. Let us assume this to be a girder attached to a chain, and a load placed at D, the effect will be to distort it into the shape shown in Fig. 6.

FIG. 6.



The deflection by the weight at D will cause a corresponding elevation at the point E, and the girder will assume the shape represented by dotted lines in the figure, to produce which a force equal to double that for a given deflection on half the beam is required, from which it is evident that the wave produced by a given weight at D, will only amount to one-sixteenth of the deflection the same weight will produce on the entire beam resting on its two ends.

In the above proposition it is assumed that the beam is supported at its centre point only; in practice, when attached to a suspension cable, it is supported at various points of its length; the difference between the wave of a supported girder and the deflection of an unsupported girder, will therefore be greater than one-sixteenth.

In order to arrive at the result by experiment, I had a model of the proposed Londonderry Bridge, on a scale of $\frac{1}{3\,3}$d of the actual span, the length being 13 feet 6 inches between the bearings, a length exceeding that of the average of the models used by the Iron Commissioners in their experiments, and is amply sufficient, due allowance being made for the scale, to determine the accuracy of the deflections on the actual girder.

The principal object of these experiments was to ascertain the de-

flection of the wave of a girder attached to a chain, as compared with the deflection of the same girder detached, which being obtained, it is perfectly easy to arrive at the deflection of the wave of any required suspension girder, because we have sufficient experiments on actual girders of various dimensions, to obtain the deflection from a given load on the same girder not attached to the chain.

These experiments gave a mean result of $\frac{1}{25}$th,* so that, it being first determined what amount of deflection is to be the limit with a given load in a given bridge, you have only to arrive by calculation at the sections of metal of a girder of the same depth which would deflect twenty-five times that amount.

To illustrate the mode of proceeding in the intended Londonderry Bridge. It was decided by Sir W. Cubitt that the depth of girder should be 16 ft. 6 ins., and that no wave or deflection should exceed 1·32 in. with 100 tons. I obtained by deduction from the deflection of the Boyne Viaduct, Newark Dyke Bridge, Britannia Tube, &c., that a girder of 3700 tons, of the depth of 16 ft. 6 ins., would be deflected 1·32 ins. with a weight of 100 tons; one-twenty-fifth, or 150 tons, is therefore the weight of girder required for the Londonderry Bridge.

The reduction of the deflection of a girder when attached to a chain may appear so great as to lead to doubt of the accuracy of the experiments; but it is not more than is fully explained by the law $\frac{l^3 w}{b d^3 \delta}$ and is consistent with such results as have been obtained in actual suspension bridges.

The Inverness Bridge, built by Mr. Rendell, had an iron parapet only 3 ft. 6 ins. deep, and yet the wave is so reduced, as reported by Mr. Rendell, as to be imperceptible to the eye when a locomotive passed over it on a truck. In the Keif Suspension Bridge, in Russia, which has a wooden trussing of about 6 ft. deep, and the Menai† and all other bridges, when any attempt, however small, has been made to give longitudinal strength to the platform, the wave has been so reduced as to be unobjectionable.

In the Niagara Bridge, which is the only bridge used for railway traffic, the longitudinal stiffness is given by timber trussing 18 ft. in depth. According to my rule, a girder of 370 tons would be required, so that no wave shall exceed 2 ins. The actual girder power of this timber trussing I estimate to be no more than could be obtained by 100 tons of good iron well arranged; so that the actual wave observed (about 4 or 5 inches) evidently does not exceed what my calculation would give, and fully bears out the result of my experiments.

* See my Paper on Suspension Bridges, published in the "Report of the British Association," 1857.

† The means used to give longitudinal strength to the Menai Bridge consists only of two beams about 12 inches square under, and 4 over, the platform; the girder power of which is much less than, according to my experiments, should be given; and should this or many other bridges now existing suffer injury in a severe hurricane, it will in no way be inconsistent with the views here expressed.

(To be Continued.)

Translated for the Journal of the Franklin Institute.

Co-efficient of Friction on Railroads.

We extract the following tables of experimental results, from a report made by a Committee of the French Society for the Encouragement of National Industry, upon a kind of shoe-brake, invented by M. Didier.

TABLE I.—*Experiments in which the car, provided with the Didier brake, was left to itself at different velocities.* Grade 0·0015 m. Rails dry. Shoes wooden.

	Total weight of car.	Weight on the shoes.	Velocity of car at beginning of experiment per hour.	Time before the shoes bore.	Whole space passed over.	Space passed under action of brake.	Calculated co-efficient of friction.
	kilometres.	kilometres.	kilometres.	seconds.	metres.	metres.	
1	10,000	8,500	16·55	3	50	36	0·035
2	"	"	54·	3	125	80	0·191
3	11,500	10,000	82·80	6	328	190	0·161
4	"	"	87·80	5	322	200	0·173
5	10,000	8,500	41·70	3	68	57	0·235
6	"	"	54·70	2·5	94	37	0·241
7	"	"	7·40	5	154	74	0·205

TABLE II.—*Experiments in which the car, with the Didier brake, was left to itself at various velocities.* Grade of the railroad 0·0015 m. Shoes wooden. Total weight of car 10,000 kilogrammes. Weight borne on shoes 8500 kilogrammes.

	Velocity at beginning of experiment per hour.	Time before the shoes bore.	Space passed over before stopping.	
	kilometres.	seconds.	metres.	
1	36	2	46	Rails dry.
2	41·7	3	68	"
3	46	3	61·5	"
4	54·7	2½	94	"
5	64·4	3½	117	"
6	63·1	3½	131	Rails wet.

TABLE III.—*Experiments in which a car, furnished with the common brake, was left to itself at different velocities.* Grade 0·0015 m. Weight of car 10,000 kilogrammes.

	Velocity of car at beginning of experiment per hour.	Space passed over before stopping.	
	kilometres.	metres.	
1	20·5	30	Rails dry.
2	57·6	213	"
3	59	170	Rails dried by wind after rain.
4	61·2	205	Rails dry.
5	68·4	251	"

NOTE.—The kilogramme = 22 lbs; the kilometre = 0·62 statute mile; the metre = 1·094 yards.

For the Journal of the Franklin Institute.

Repairs and Renewal of the Roche-Bernard Suspension Bridge. From a description given by M. Noyon, Engineer. Translated by J. Bennett.

Part First.

The first part of this notice presents the circumstances and causes of the accident which befell the Roche-Bernard bridge in the hurricane of Oct. 26th, 1852, and an examination of the modes proposed for its consolidation and protection against the action of storms; the second describes the works effected for accomplishing this two-fold result, as well as different processes and details of execution peculiar to the work.

Fall of the Platform.—On the 26th Oct., 1852, the platform of this bridge, being violently disturbed by a tempest which raged for two days among the Morbihan hills, was broken into many parts, and almost entirely precipitated into the Vilaine River. After the rupture, which was instantaneous, there remained but three portions; one between the centre of the span and the right bank abutment, the two others near the piers.

Happily, no one was upon the bridge at the time, though, a few minutes before, a stage coach passed over it; the horses swayed by the wind, frightened by the noise and the insecure foothold, reared and baulked; but the driver having mastered them, urged them at a full gallop, and so escaped the danger.

The bridge-keeper was the only one who witnessed the accident, and he could give but vague and contradictory accounts of it; so that all would have been left to mere conjecture, but for the clear indication of the causes of the disaster, derived from an inspection of engineers the day after the event, and from the nature of movements to which suspension bridges of large span are exposed.

*Condition of the Cables.**—From the report of M. Grégoire, the suspension cables suffered no change but that arising from the shocks against the porches at the points where they enter the masonry, and was limited to tearing away the ligatures in these parts; so likewise for the retaining cables, at their entrance into the pedestals which covered the mooring chambers. In the galleries, some five or six wires per cable were cut by the friction against the side masonry. The mooring cables were uninjured. The only trace of vibration naturally sustained by the whole system of suspension was the cracking of the paint and dried oil varnish surrounding the cables throughout their length.

Condition of Masonry.—No fissures were discovered in the resisting parts. The cut-stone masonry of the piers which bore the cast iron plates receiving the friction rollers was undisturbed, and the mortar at the joints was intact. In the mooring chambers, where all the points of support are upon the rock itself, there were found slight

* Suspension cables bear the platform; retaining cables, the inclined part between towers and galleries; mooring cables secure the retaining of each bank.

cracks in the cement lining which covered the masonry revetment of the vertical pits, near the cushions, which must have been moved by the sheering and slackening of the suspension cables.

There was a partial destruction of the pedestal cornices and pier crowns, near the entrances of the retaining and suspension cables.

On the down-stream side some stones were raised and moved; on the up-stream some were thrust violently outwards, and fell upon the platform, or upon outside of pier.

Condition of Platform.—Three portions of the platform were left suspended to the cables; the first, on the opposite side of Roche-Bernard, had 19 suspension beams, 17 of which were fast in the stirrups at both ends, while the two others were, the one nearly and the other wholly, freed from them on the down-stream side.

A second portion, composed of 22 suspension beams and covered with the flooring, was separated from the first by a space of 21 intermediate rods; on the up-stream side, 19 of the beams were in their stirrups, while on the down-stream, 10 only, in the middle part, were partially or wholly fast to them. The connexion of the carpentry was all that prevented the fall of the extreme portions.

A third portion, on the Roche-Bernard side, was composed of 20 beams, completely fast in the stirrups on the up-stream side, and free from them on the down-stream side.

Rods, Stirrups, and Yokes or Supports.—The suspension rods answering to the broken portions of the platform, were for the most part intact on down-stream side; ten only were broken or bent, the others having preserved their forms. The stirrups were in their place, two only being ruptured from defective iron. But on the upper side, the rods bear marks of violent commotions, being all more or less damaged, while some were bent double, and one turned completely over the cable. Some of the yokes were broken.

Ruins of the Platform.—The platform from its fall was naturally broken in all directions; the railing which had been bolted to the suspension beams was detached. The five fallen portions may be considered as of equal lengths with the suspended, and it may be admitted, that at the moment of rupture, the platform was divided into eight parts, containing each 22 or 23 beams.

Different Observations.—1st. The friction rollers upon which rest the suspension cables, at the origin of the parabolic curve, had all slid upon their plates towards the river, and were displaced from two to five inches.

2d. The joists of the flooring, the stringers of the side walks, the only pieces connected with the suspension beams, were mostly rotten at the core. The side railing, as well as other parts of the carpentry, with fourteen years use, were no better, and were completely smashed in the fall of the platform.

3d. The distance between the suspension cables of the two sides, being greater than the length of the beams, the latter naturally tended to escape from their stirrups, especially in the central part. Great pins had been placed back of the stirrups to prevent the sliding; they

were wholly detached from the beams that had fallen, and on the down-stream side of those in suspension were all more or less bent.

Before drawing conclusions, it may be well to examine the different movements most frequently produced by suspension bridges of large span, under the action of wind.

Vertical Oscillations.—In all bridges the curves of the chains or cables are easily deranged, and the changes produced by an increased or diminished tension at any point, occasion marked perturbations in the conditions of equilibrium.

Thus, when a transient load presses a portion, p, of the platform (Fig. 1), this portion and the corresponding element, m, of the cable falls, and on rising to resume its normal position it passes by it, and oscillates until the quantity of motion imparted is consumed by the resistances of the displaced mass. While the points m and p thus vibrate, other points, n and q, on the other side of the summit, o, of the curve oscillate in an opposite direction. In virtue of the flexibility of the system, they fall when the first rise, and *vice versa*. The summit of the cables is also displaced, passing right and left, above and below its normal position.

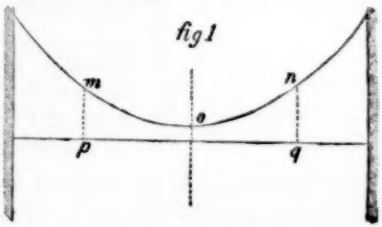


fig 1

The effect in this case is more apparent as the disturbing force is in greater ratio to the mass of the bridge; if this force is renewed at short intervals, the agitation increases rapidly, and may acquire sufficient intensity to produce a rupture of the cables.

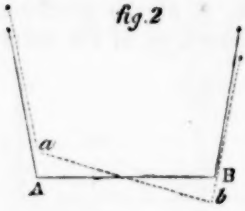
The wind exerts an action similar to that of the transient load. Pressing against the under surface of the platform, it diminishes the weight borne by the cables, which from their tension are raised, and fall when the disturbing force is diminished or ceases to act. Hence arise vertical oscillations, whose amplitude varies with the violence or duration of the wind. In a storm, when squalls succeed at short intervals, such oscillations are produced at different points, and may have a development capable of deranging or utterly destroying the most solid platforms.

The vertical oscillation, being an immediate and natural consequence of the flexibility of the cables, of the facility with which they are disturbed, and of the little rigidity of the whole system, all else being equal, it should be less marked, as the mass is more considerable, and as the ratio of the rise to the chord of the cables is smaller; especially in the middle and extremities, because these parts for a considerable distance differ but little from a straight line, and because the platform is nearly directly attached to the cables, or made fast with the piers; on the other hand, it should be very marked at $\frac{1}{8}$th of the span from the origin, where the rods are all long, and where the cables, for the same horizontal projection, have a greater development, and accordingly more flexibility.

Vertical vibrations being necessarily frequent, wear upon the bonds of carpentry in platforms, and at length injure and displace them, and by reason of the great amplitude which they attain, occasion some inconvenience to the travel, for the movements impressed are in some cases similar to the pitching of ships.

Transverse Oscillations.—When two corresponding elements of the up-stream and down-stream cables oscillate in opposite directions, either from direct actions or reactions, one side of the platform is raised above its normal position, while the other falls below it, with an effect similar to the rolling of ships. This movement, always manifest in high winds, is very prejudicial to the platform, causing the travel to be laborious, if not impossible, while an absolute displacement of 8 inches of the points A and B causes a difference of 16 inches in level between the heads of the bridge.

fig. 2



Undulations.—If the vertical oscillations effected at the same time in different parts of the cable are continuous and concurring, they are spread in succession, and unite, so that the platform undulates like the sea agitated by the wind. Though generally small in amplitude, they disturb the carpentry work, and by reason of the alternate flexures in opposite directions finally injure the elasticity of the wood.

Raising of the Platform.—The wind frequently acts simultaneously upon many points of the under surface of the platform. The cables being thus relieved of a portion of the weight usually borne by them, rise and draw up with them the platform; when the disturbing cause ceases, they fall, and oscillate about their initial position before definitely resuming it.

This effect does not occur, at least to any great extent, except in high winds or great squalls, and at quite distant intervals. Should they become continuous, the whole bridge would oscillate without interruption, and would impart a *vis viva* sufficient to break the platform and the cables.

When movements of this kind occur, the platform is not, properly speaking, raised by the wind; it is simply drawn by the tendency of the cables to assume a curvature corresponding with the new conditions of equilibrium, determined by the disturbing force, and the suspension beams do not cease to rest upon their stirrups.

Horizontal flexure and translation of the Platform.—It is quite natural to suppose that the platform of a suspension bridge, under the action of wind, would be deflected in the middle (the same as a stick of timber secured at the ends and uniformly loaded), and even be displaced in mass, when not solidly fastened to the abutments; but such is not the case; the horizontal flexure of the platform of the Roche-Bernard bridge during the greatest storms did not exceed from 8 to 10 inches.

As to the motion of translation in mass, various observations have shown that it was almost inappreciable; with so great resistances opposed to the action of the wind, it could not reach an appreciable extent. Thus any portion, M N, of the platform could not be horizontally displaced without rising a little, since the points A and B are fixed, and the rods are rigid. Now the rising must consume a large part of the acting force; and as in great storms there are short intervals of lulls, the platform is brought back quickly by its own weight to its normal position; so that the effects of the wind disappear nearly as soon as they are produced.

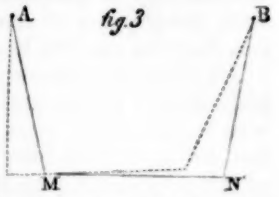


fig. 3

On the other hand, the friction of the rods upon their yokes, the form of the suspension cables, the small space generally existing between them and the platform in the middle of the span, and finally, the more or less perfect solidity of the different parts, all combine to prevent oscillations and displacements in a horizontal direction.

Causes of the Fall of the Platform.—The simultaneous existence of the above described movements, and their intensity during the tempest of October 26th, explain the fall of the platform of the bridge. Probably, after having been strained for a long time in all directions, it oscillated *en masse* many times in succession, and its rupture in eight parts was effected instantly, during a squall, by an oscillation of this kind.

The movement impressed upon the whole system by the first circumstance, the disorder occasioned by it, and the developed *vis viva* imparted to the different parts of the platform after their separation, impulses which drove them far from their normal positions. Then each of them swung separately around their points of attachment, without a cessation of their oscillations, and these two movements, aided by the permanence of the wind and the discordant oscillations, produced wrenches, shocks, and successive displacements, which ended in causing upon the down-stream side the escape from the stirrups, upon which the beams simply rested, and which was inevitable by reason of the obliquity of the rods to the platform, and their tendency to depart from the axis of the bridge, and especially from the inclination A B (Fig. 2), which the direction of the wind, blowing from down-stream up, caused the beams to take.

The up-stream cables then supported alone, though but for a short time, all the weight of the detached platform, and this enormous surcharge so shortened the length and sagitta of the corresponding retaining cables, that they beat against the mooring pedestals so severely as to overthrow four courses of strong cut stone masonry.

The demolishing of the upper part of the sides of the porch facing the river is attributed to the shock of the down and up-stream suspension cables, which, suddenly freed from a considerable load, the first after the escape of portions of the platform, the second after their fall, must have vibrated violently around their final position.

The up-stream cables, on account of their accidental surcharge, oscillated more violently than the others, and so caused more damage to the masonry of the up-stream than the down; the same was the case with the slipping of the friction rollers, which differed from 1 to 1½ ins. between the two heads of the bridge.

As to the displacement of the two fragments of platform, which remained near the towers, and the rupture of their connexions with the wall beams and porches, they were due to the whole system of suspension having been suddenly drawn to the up-stream side, when the cables of this side alone supported the five portions of platform which had escaped from their down-stream stirrups, and to the disorderly oscillations of these parts around their points of fixture.

From the above developments, the fall of the platform is attributed, 1st, to the great mobility of the suspension system; 2d, to the decayed condition of the carpentry connecting the platform beams; 3d, to the absence of all proper means of securing the beams to their stirrups, and to the fact that the vertical oscillations of suspension bridges constitute the most dangerous movements to which they are generally exposed, since, being caused by small surcharges and light winds, they are nearly continuous, and may attain in some cases an amplitude to break the most solid structures.

The Council General of the "Ponts et Chaussées," in approving the project of rebuilding the platform, prescribed a complete fixture of the ends of the beams in their stirrups, and a study of the dispositions required for a more rigid suspension, and for the prevention of oscillations, swingings, and lifts, during tempests.

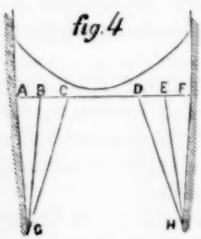
It may be well to examine among the proposed projects those which with a satisfactory solution best reconcile the dispositions of the bridge with the exigencies of the navigation of the Vilaine.

Means proposed and adopted for consolidating the system of suspension.

Guys.—The most simple and natural method first proposed was a system of guys.

If all the platform beams were solidly connected together on each side of the axis of the bridge by a wire cable fastened to the towers, and if to the cable were attached inclined guys, such as G B, G C, H D, H E, with their ends firmly anchored in the ground or bottom of the river (Fig. 4), it could not experience vertical oscillations of a great amplitude; but it would be exposed to movements resulting from partial changes produced by the wind, or the passage of heavy loads in the intervals A B, B C, C D, &c. But it could not be put in practice upon the Roche-Bernard bridge, on account of interrupting the navigation.

fig. 4



It is true this inconvenience might be avoided by substituting hori-

zontal guys, placed nearly at the height of the roadway. These guys, two on each side, might be secured at their ends, T, to the cables A B, A′ B′ (Fig. 5), connecting the beams together, and at their other ends, in masses of masonry, M, disposed for this purpose upon the hills bordering the Vilaine. Unfortunately, the points, M, could not be had at a less distance than 218 yards from the points, T, and so it would be impossible to give them sufficient rigidity to answer a good purpose; and even admitting that they might have been stretched in nearly a right line, they would by no means be opposed to the vertical oscillations of the platform around their points of attachment, M (Fig. 6), and their extremities, T, could be easily displaced upon the vertical T T′; for an elongation of ·04 of an inch would suffice to lower the point, T, over a yard.

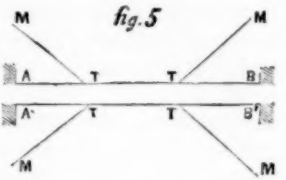


fig. 5

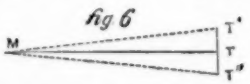


fig 6

M. Leblanc's System.—In a letter addressed to the Minister of Public Works shortly after the fall of the bridge, M. Leblanc, the Chief Engineer, suggested a plan which, in his judgment, would prevent the rising, and so the removal of the platform.

Thus he describes it:

"If it were possible to establish between the towers of suspension bridges a rigid and unyielding bar of iron, to which the platforms might be fastened, they could not be raised; but though it may not be possible to establish such a bar, it is easy by means of two cables, *a i b*, *c o d* (Fig. 7), with their convexities turned towards each other, and connected by vertical ties, to form a rigid system, equal to that of the iron bar. I have proved it with ropes upon a great length.

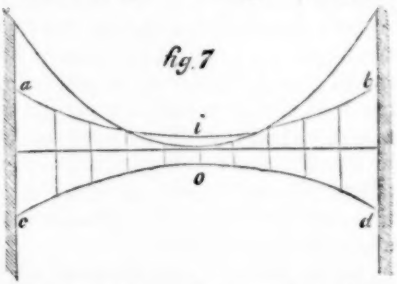


fig. 7

"By applying such a system of rigid axes, either above, below, or at the sides of, the platforms, so as to receive no part of the weight of the bridge, and arranged so as to oppose oscillations exceeding 4 inches, the accidents which have befallen the Beaucaire and the Roche-Bernard bridges might have been prevented."

Though it might be difficult upon this simple statement to account for the efficiency of this method, and to appreciate, *à priori*, the merit of an untried arrangement, it would seem to present much rigidity, and by reason of the numerous connexions between the auxiliary cables, and between the platform and the cables, it would be impossible for any point of the platform to rise or fall without creating in other parts resistances which should oppose its movement and arrest it at once.

Unfortunately, to apply this system without obstructing the navigation, it would be necessary to place one of the cables below the platform and the other above, and consequently to make the points of fastening quite high in the porches, and to pierce the masonry through and through, and so mutilate and disfigure the edifice. On the other hand, the upper cable would have been wholly visible, and would have an unsightly appearance.

Finally, the difficulty of making eight holes, from 16 to 23 ft. deep, through very hard granite masonry, traversed in all directions with iron bars and cramps, besides other reasons which might be enumerated, forbade the adoption of this system.

Oudry's System.—Another more complicated mode of consolidation somewhat similar to the above, was proposed by M. Oudry, engineer:

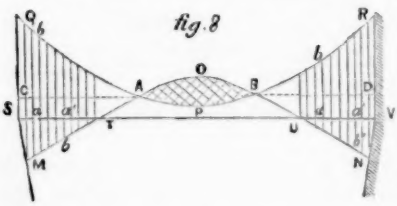


fig. 8

Let Q A P B R (Fig. 8), be a suspension cable, and M T A O B U N, a counter cable, with the portion A O B, parabolic, and straight in the parts, M A, and B N.

If the two cables are firmly united at A and B, their intersection, and if the space comprised between the parabolas, A O B and A P B, is exactly filled by a rigid spandril, such as A O B P, and the points A and B are secured to the towers by horizontal guys, A C and B D, the points, A, B, are in an invariable position; for when the first tends to approach or recede from the adjoining abutment, S, the invariable form of the fish-bellied spandril, A O B P, determines a second inverse motion in respect to the opposite abutment V; every displacement of the points A, B, exacts the receding of one of them from its adjoining abutment, an impossibility, since the first of these points is retained by the two inextensible rods, C A, and M A, and the other by the two rods, B D, and B N.

The fish-belly being invariable in form and position, the portion of the platform directly attached to the arc, A P B, is in a similar condition, however little the counter cable may be secured to the platform at the points, T and U.

As to the invariable form of the platform in the parts, S T and U V, it may be attained by connecting the ends of the beam with the cables, Q A and B R, by vertical wrought iron rods, *a b*, of a certain rigidity, with symmetrical oblique wire rods each side of the vertical, bound together with straight rods at their points of crossing. The invariability is also greatly increased by connecting with the platform the pendent rods, *a' b'*, required for supporting the counter cable, and for holding straight the portions M A and B N.

Thus the efficiency of this system rests solely upon the unchangeable form and position of the fish-belly, and of the portions of the platform not directly secured to it; it exacts, 1st, the crossing and connexion of the suspension cables with the counter cables; 2d, the use of horizontal guys fastened in the abutments; 3d, the establish-

ment of oblique rods, constituting with the bridge rods an unchangeable trellis work.

The most of these conditions cannot be realized for the Roche-Bernard bridge without difficulties and injury to the appearance of this beautiful monument, and a trial of this system was never entertained a single instant.

Counter Cable resting upon the Ends of the Beams.—Another method, which has already been applied to several suspension bridges in France and England, consists of a safety cable, a kind of counter cable, solidly secured to the abutments at the level of the platform, and resting upon the ends of the beams.

Such a cable increases the rigidity, but does not completely prevent the oscillations of the platform, though it may diminish their amplitude, especially if there is a certain length given to the sagitta of curve.

If a point, *m*, of the platform lowers by the effect of a surcharge, the element of suspension, *p*, also descends; consequently, the cable changes its form, and the point *q*, corresponding with the point *p* (Fig. 9), tends to rise; but as the counter cable remains stiff at *n*, and presses strongly upon the platform, it is opposed to the motion of the point, *q*. On the other hand, when the surcharge ceases to act, the point, *m*, returns to its initial position, and can only surpass it a small quantity, since the counter cable on returning to its first position acts so much the more energetically upon the platform at the point, *m*, as it has experienced a greater than the normal tension, by reason of the reaction, which determines the tendency of the point, *n*, to rise at the same time with the point, *q*.

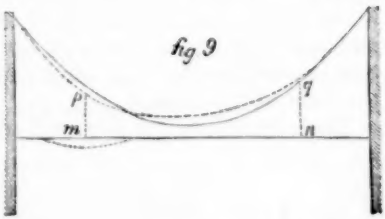


fig 9

Thus, the acquired velocity of the point, *m*, if not destroyed, is at least diminished by the resistance of the counter cable; consequently, the amplitude and duration of the oscillations become much less, and as the *vis viva* developed in the suspended mass is neutralized almost immediately, the disturbing cause may be renewed, even at short intervals, without causing a serious displacement of the platform.

This method is especially effective against the action of the wind; it evidently prevents the lifting *en masse;* it opposes and so arrests promptly the partial oscillations, and wholly prevents tumultuous movements and the disorder natural to a system which offers no opposition to an accumulation of *vis viva* imparted by an incessant cause, and producing by a series of uninterrupted oscillations, terrible shocks which cannot be resisted.

That this method may produce satisfactory results, it is important that it should have strength enough to contend against the most violent winds; the counter cable must therefore be made of a great many

wires, as the sagitta of the curve equal to the convexity of the platform, is very small compared with the span, and as their tensions on the rising of the platform are inversely proportional to this rise.

Various reasons forbid the application of this system to the bridge. It would have been necessary to establish the mooring points in the piers of the porches, which would be attended with the inconvenience already indicated in the method of M. Leblanc.

On the other hand, these points would have to be at least 2 ft. above the platform at its origin, and thus the rise of the curve of these cables would only be 4·26 ft. — 1·96 ft. = 2·3 ft.; so that very small variations of temperature would produce a marked increase in length of sagitta, by which the efficiency of the method would be much diminished.

Finally, on account of the position of the mooring points, the safety cables could not rest upon the first twenty beams, and so the results would be incomplete.

Counter Cable below the Platform.—The combination finally adopted differed but little from the preceding, but is much more satisfactory; it consists in placing the safety or counter cable below the platform, and securing it to the ends of the beams by rigid rods. In this position it would produce an effect similar to that of a cable resting upon the ends of the beams.

Thus, when the point, *m*, of the platform (Fig. 10) is lowered, the point, *p*, of the counter cable will fall, being deprived of its support; but the portion, *izd*, of the curve will not change its form. Therefore, when the point, *s*, of the suspension cable, corresponding to the point *r*, tends to rise, it will be opposed by the resistance of the element, *z*, which cannot rise, but by a total change of the counter cable, a difficult matter on account of its length and its weight.*

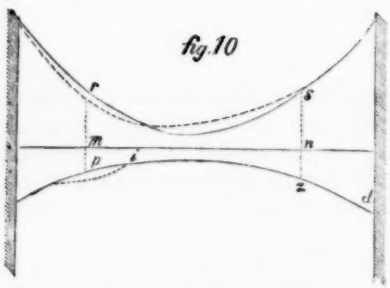


fig. 10

When, by any cause, oscillations occur in the platform, the resistance of the counter cable will arrest their development, and prevent an amplitude sufficient to impair the framings of carpentry.

The movements of suspension being thus thwarted at each instant, the centre of gravity of the mass can never acquire a great velocity nor be much displaced; consequently, there is no fear of shocks arising from the accumulation of *vis viva*, or of a repetition of the accident which befell the Roche-Bernard bridge.

The efficiency of the system in question being so much the greater as the changes in the counter cable, from dilation or extension of the

* There is a difference in the reactions of the counter and suspension cables, the latter bearing a permanent load, while the others are simply supported, and the equilibrium of the latter depends upon the tensions to which they are subjected, and that of the former only upon the immobility of the platform.

wires, are less prominent, it is essential to give a good length to the sagitta.

Without prejudice to the navigation of the Vilaine, it could be set at 25 ft. Moreover, to increase the rigidity of the system, the mooring points of the counter cables are set outside of the vertical planes passing through the ends of the beams; so that the curve described by each of them is projected horizontally in a curve line, with a sagitta of 6·5 ft.

This secures against horizontal movements which the wind tends to impart to the platform.

Various provisions.—The administration prescribed placing under the platform a course of substringers, 7·8 ins. by 8·6 ins. square, corresponding with the interior stringers of the side walks, firmly connected with the latter and the suspension beams, either by bolts or loops.

It further decided to have the ends of the platform invariably fixed to the towers. This was done by bolting the four first beams of each side, as well as their corresponding stringers, upon two strong pieces of oak, made fast to the masonry at the level of the torus of the base of the towers.

To prevent the beams from slipping out of their stirrups, there was placed at each end, in the rear of the latter, a horizontal pin, passing through and projecting 2 inches upon their side faces.

Change in System of Mooring Cables.—The dispositions adopted by the Chief Engineer, Leblanc, for mooring the cables, were so defective that he was the first to point out their principal unfitness.

Without following the details, suffice it to say, that though in point of solidity M. Leblanc had left nothing to be desired, yet the advantages in this respect were completely annulled by the conditions of its application, and beside the radical faults pointed out by this engineer, it was attended with other serious inconveniences. Thus, in the part where the mooring cables are inflected to penetrate the vertical pits, they spread out in sheets 4¼ feet wide, so near the bottom and sides of the tunnels as to leave no room for introducing the arm. Between this point and that of the union of the retaining with the mooring bundles, forming two layers, one above the other, they were close to the ground, and so the entrance to the covering pedestals, as well as to the vertical wells, was inaccessible, for the wide sheets occupied the whole width of the gallery, so much so that it became necessary, for preventing friction, to separate them from the masonry by wooden wedges. To this we must add the constant strife against the filtering water of the rock cliffs, where recourse was had to various expedients, such as cement packing, side draining, and plank roofing.

These means, devised mostly by the keeper of the bridge, were not sufficient to protect the wires from the effects of moisture, and for a long time all the accessible parts were covered with putty and greasy substances, which, annually renewed, ended by forming a thick and nearly impermeable layer. Unfortunately, this coating could not be applied to the under side of the sheetings, nor upon the portions

buried in the mooring wells, precisely where it was most needed, and where the wires were directly exposed to the oozing of water, or moisture of the ground.

Such a state of things caused much uneasiness, and the upper administration were urgently solicited to provide a prompt and energetic remedy against an evil which time would aggravate; and for this purpose proposals were made for the construction of new galleries, and for the repairs and removal of the mooring cables on each bank. In furtherance of these proposals it was stated, that there was an utter ignorance of the state of the wires in the mooring bundles, as certain parts had never been visited since they were put in place, while there was every reason to suppose that a great number had been attacked by rust.

Before acting upon these proposals, the Council recommended an inspection of the cables, to be well assured of the degree of solidity of their various parts. As the suspension and retaining cables as far as the entrance to the pedestals had been carefully examined after the fall of the bridge, when free from all load, they could be unligatured, opened, and separated, and as it had been proved that all the strands were in a good state of preservation, the inspection was limited to the mooring cables proper.

After taking off completely the continuous ligature enveloping the horizontal part in the cross gallery connecting the two vertical wells, hard wood wedges were driven in at different points, and the wires were held apart, so as to see to the centre of the cables. Marked traces of rust were found throughout. Especially near the pillow blocks, at the rounding of the corners, the wires were much altered, and there were found small reservoirs of water discolored with oxide of iron. This water, which was probably introduced in a state of vapor through the voids of the strands, could not have accumulated at these points without having traversed the vertical parts. It was natural, therefore, to suppose that the latter, which were directly exposed to the oozings and drops from the galleries, were also injured.

In the wide sheets which formed the cables on their entrance to the mooring wells, the wires, though marked with rust at many points, were in general much better preserved, much drier, from being better ventilated, and from being without ligatures and a greasy envelope, and so allowing the water which reached them to pass off along them.

To satisfy the prescriptions of the administration, it remained to ascertain whether the suspension and mooring wires had lost any part of their relative or absolute strength.

This question was settled by many trials of their resistance, and by a comparison made with that assigned by the Chief Engineer upon the construction of the bridge.

As for the suspension cables, experiments were made upon wires of strands broken by extreme tension, or worn by the friction of the supporting yokes. These strands, with the exception of those which had shrunk, having been changed, either by a loss of fibrous texture or from the exterior fibres being bruised or cut, the measure of their strength may be regarded as the inferior limit of the intact wires.

Some trials were made upon strands of suspension cables, near the supporting rollers, where the permanent tension is the greatest; thus all the experiments being made upon wires in the most unfavorable condition, their resisting tension may be considered as a minimum of the mean strength of all the strands of the suspension cables.

The results of these trials show:

1st. That the resistance per ·00155 square inches of section was 172·62 lbs. for 34 strands of broken wires, stretched or worn by the rod yokes; 155·95 lbs. for 8 strands near supporting rollers.

2d. That the mean resistance for the 42 trials was 155·15 lbs.

3d. That the mean section of the wires experimented upon was ·014 square inches.

In the description of the Roche-Bernard bridge, M. Leblanc attributing to the wires a mean resistance of 167·62 lbs., the loss of strength would seem to be 12·47 lbs. This result would appear to be too great, and could not be accepted without verification; and on an examination it was found that M. Leblanc had committed an error, and that the primitive force was below 167 lbs.

Without enumerating the calculations, it would seem that the primitive resistance should be set at 158·79 lbs., and that the loss of force since the construction of the bridge did not exceed (2 kil. per mille. square or) 2846 lbs. per square inch.

It was thought that these changes were due to the molecular condition of the wires, arising on the one hand from the influence of the atmosphere, and on the other to the permanent work, and continual vibrations of the cables.

Loss of Force in Mooring Cables.—To arrive at the degree of change in these parts, trials were made upon 16 strands much injured by rust, and upon 12 strands in good order taken from the sheets near the entrance of the pits. The latter at the moment of rupture supported a tension of 154·38 lbs. per ·00155 square inch, while the other broke under a tension of 148·51 lbs., a loss of 10·28 lbs. per section of ·00155 square inches.

This notable diminution of relative force arises solely from the change of primitive tenacity by the rust. As for the absolute loss of force, resulting from the disappearance of material consumed by rust, it was scarcely appreciable, for the mean section in good order was ·013779 square inches, and that of the rusted was ·013733 sq. inches, or 4·76 lbs. per strand.

Consequently the presence of moisture had changed the molecular condition of the wires so much, that the absolute force of some was reduced 91·37 lbs.

These results could not fail to be alarming. It was fair to suppose that a third of the wires of the mooring cables, were in a similar condition, and so it was feared that the resistance of the cables might be diminished $\frac{5600}{3} \times 91{\cdot}37 = 170{,}557$ pounds.

This figure was a potent argument in favor of the project, and would

alone have sufficed for its adoption, even if another circumstance had not called for the enlargement of the galleries and the moving of the mooring cables.

The establishment, first ordered, of a counter cable, and a course of stringers under each side of the platform, would increase the weight of the suspension by 72,600 pounds, and the wires, even in the parts which were not to be repaired, having lost a portion of their primitive force, the permanent work to which they would be subject in these new conditions, would have exceeded the limit of 12 kil. per mille. square of section (17,075 lbs. per square inch), first assigned them. The administration, therefore, decided that there should be a third cable upon each head of the bridge, which should bear one-third of the suspension rods. Now the old galleries being completely occupied by the spreadings of the primitive cables, where the retaining bundles are joined with the mooring, it was of course impossible to introduce the new cables; it was therefore necessary to radically change the dispositions and dimensions of these galleries, and to give another form and direction to the mooring bundles, that is to say, to execute the different works proposed, but founded upon wholly different considerations. So that, to resume, independently of the reconstruction of the platform, there were three operations, to wit:

1st. The enlargement of the galleries, and change in the system of mooring cables.

2d. The establishment upon each head of the bridge of a third suspension cable.

3d. The instalment of two safety cables, bound to the ends of the beams by rigid rods.

These operations will be described in Part II.

(To be Continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Strength of Materials: Deduced from the latest experiments of Barlow, Buchanan, Fairbairn, Hodgkinson, Stephenson, Major Wade, U. S. Ordnance Corps, and others. By CHAS. H. HASWELL, Civil and Marine Engineer.

No. 4.

(Continued from page 43.)

GIRDERS, BEAMS, LINTELS, &C.

The Transverse or Lateral Strength of any Girder, Beam, Bressummer, Lintel, &c., &c., is in proportion to the product, of its breadth and the square of its depth, and also to the area of its cross section.

The best form of section for Cast Iron girders or beams, &c., is deduced from the experiments of Mr. E. Hodgkinson, and such as have this form of section (I) are known as Hodgkinson's.

The rule deduced from his experiments, directs as follows:—Area of bottom flanch, six times that of the top flanch. Flanches connected

by a thin vertical web, only sufficiently thick to have the requisite lateral stiffness, and tapering both upwards and downwards from the neutral axis, and in order to set aside the risk of an imperfect casting, by any great disproportion between the web and the flanches, it should be tapered so as to connect with them with a thickness corresponding to that of the flanch.

When Girders are subjected to impulses, and are used to sustain Vibrating loads, as in bridges, &c., the best proportion between the top and bottom flanch, is as one to four, as a general rule, they should be as narrow and deep as practicable, and should never be deflected to more than one five-hundredth of their length.

In Public Halls, Churches, and Buildings where the weight of people alone are to be provided for, an estimate of 175 pounds per square foot of floor surface is sufficient to provide for the weight of flooring and the load upon it.

In Store Houses and Factories, the weight to be provided for, should be estimated at that, which may at any time be placed thereon, or which at any time may bear upon any portion of their floors: the usual allowance, however, is for a weight of 280 pounds per square foot of floor surface.

In all uses, such as in buildings and bridges, where the structure is exposed to sudden impulses, the load or stress to be sustained, should not exceed from one-fifth to one-sixth of the breaking weight of the material employed, but when the load is uniform or quiescent, it may be increased to one-third and one-fourth of the breaking weight.

An open web girder or beam, &c., is to be estimated in its resistance, on the same principle as if it had a solid web. In cast metals, allowance is to be made for the loss of strength due to the unequal contraction in cooling of the web and flanches.

In cast iron, the mean resistance to crushing or compression and extension, are as 5·5 to 1, and in wrought iron, as 12 to 23; hence the mass of metal below the neutral axis, will be greatest in these proportions, when the stress is intermediate between the ends or supports of the guides, &c.

Wooden Girders or Beams, when sawed in two or more pieces, and slips are set between them, and the whole bolted together, are made stiffer by the operation and are rendered less liable to decay.

Girders cast with a face up are stronger than when cast on a side, in the proportion of 1 to ·959, and they are strongest also, when cast with the broadest flanch up.

The following results of the resistances of metals will show how the material should be distributed, in order to obtain the *maximum* of strength with the *minimum* of material:

	To Tension.	To Crushing.
Wrought Iron,	23 tons.	12 tons.
Copper,	16 "	3 "
Cast Iron,	8 "	51 "
	8 "	37 "

Hence, In a wrought iron beam, the upper flanch should be as 23 to 12, or 2 to 1.

The best iron has the greatest tensile strength, and the least compressive or crushing.

The relative strength of girders or beams, cast vertical or horizontal, is as 536 to 514, or as 1 to ·96.

The outline of a girder or beam, both in depth and width of bottom flanch, may be reduced from the required dimensions in the middle, or at the end, as the case may be, at points intermediate between the centre and supports, or end and fulcrum, to correspond to the weight or stress to be borne.

When the Top flanch, the thickness of the web, the length and the depth are unaltered, the web being thin, the strength of the girder or beam, is nearly in proportion to the area of the bottom flanch. (See Enquiry of Samuel Hughes, C. E., &c., Artizan, pp. 148-9.)

The most economical constructions of Girders or Beams, with reference to attaining the greatest strength, with the least material, are as follows:—The outline of their top, bottom, and sides, should be a curve of various forms, according as the breadth throughout is equal, or the depth throughout is equal, and as the girder or beam is loaded only at one end, or in the middle, or uniformly throughout.

When the Girder or Beam is Fixed at one End, and Loaded at the other.

1. *When the Depth is uniform throughout the entire length.*

The depth being uniform: The section at every point must be in proportion to the product of the *length*, *breadth*, and *square of the depth*, and as the square of the depth is in every point the same, the *breadth* must vary directly as the length, consequently, each side of the beam must be a vertical plane, tapering gradually to the end.

2. *When the Breadth is uniform throughout the entire length.*

The breadth being uniform: The *depth* must vary as the *square root of the length:* hence the upper or lower sides, or both, must be determined by a parabolic curve.

3. *When the section at every point is similar, that is, a Circle, an Ellipse, a Square, or a Rectangle, the sides of which bear a fixed proportion to each other.*

The section at every point, being a regular figure: For a circle, the diameter at every point must be as the *cube root of the length*, and for an ellipse, or a rectangle, the *breadth* and *depth* must vary as the *cube root of the length.*

When the Girder or Beam is Fixed at one End, and Loaded uniformly throughout its Length.

1. *When the Depth is uniform throughout its entire length.*

The depth being uniform: The *breadth* must increase as the *square of the length.*

2. *When the Breadth is uniform throughout its entire length.*

The breadth being uniform: The *depth* will vary directly as the length.

3. *When the Section at every point is similar, as a Circle, Ellipse, Square, and Rectangle.*

The Section at every point being a regular figure: The *cube of the depth* must be in the ratio of the *square of the length.*

When the Girder or Beam is Supported at Both Ends.

1. *When Loaded in the middle.*

The *constant* of the beam, or the product of the breadth and the square of the depth, must be in proportion to the distance from the nearest support; consequently, whether the lines forming the beam are straight or curved, they meet in the centre, and of course the two halves are alike.

The beam, therefore, may be considered as one of half the length, the supported end corresponding with the free end in the case of beams one end being fixed and the middle of the beams similarly correspond with the fixed end.

1. *When the Depth is uniform throughout.*

The depth being equal: The *Breadth* must be in the *ratio of the length.*

2. *When the Breadth is uniform throughout.*

The breadth being uniform: The *Depth* will vary as the *square root of the length.*

3. *When the Section at every point is Similar, as a Circle, Ellipse, Square, and Rectangle.*

The section at every point being a regular figure: The *cube of the depth* will be, as the square of the *distance* from the supported end.

When the Girder or Beam is Supported at Both Ends and Loaded uniformly throughout its length.

1. *When the Depth is uniform.*

The depth being uniform: The *breadth* will be as *the product of the length of the beam, and the length of it on one side of the given point,* less the square of the *length on one side of the given point.*

2. *When the Breadth is uniform.*

The breadth being uniform: The depth will be as *the square root of the product of the length of the beam, and the length of it on one side of the given point, less the square of the length on one side of the given point.*

3. *When the Section at every point is similar, as a Circle, Ellipse, Square, and Rectangle.*

The section at every point being a regular figure: The *cube of the depth,* will be as the *product of the length of the beam, and the length*

of it on one side of the given point, less the square of the length on one side of the given point.

General Deductions from the Experiments of Stephenson, Fairbairn, Cubitt, Hughes, &c.

Fairbairn shows in his experiments that with a stress of about 12,320 lbs. per square inch on cast iron, and 28,000 lbs. on wrought iron, the sets and elongations are nearly equal to each other.

A Cast Iron beam will be bent to one-third of its breaking weight, if the load is laid on gradually, and one-sixth of it, if laid on at once, will produce the same effect, if the weight of the beam is small compared with the weight laid on.

Hence, Beams of cast iron should be made capable of bearing more than six times the greatest weight which will be laid upon them.

In Wrought Iron beams, the upper flanch should be larger than the lower, in the ratio of 2 to 1. The breaking weights in similar beams are to each other as the squares of their like linear dimensions. That is, the breaking weights of beams are found by multiplying together the area of their section, their depth, and a *constant*, determined from experiment on beams of the particular form under investigation, and dividing the product by the distance between the supports.

Cast and wrought iron beams, having similar resistances, have weights nearly as 2·44 to 1.

The range of the comparative strength of girders, of the same depth, having a top and bottom flanch, and those having bottom flanch alone, is from having but a little area of bottom flanch to a large proportion of it, from less than one-half to one-quarter greater strength.

A box beam, or girder, constructed of plates of wrought iron, compared to a single rib and flanched beam **I**, of equal weights, has a resistance as 100 to 93.

The resistance of beams, or girders, where the depth is greater than their breadth, when supported at top, is much increased. In some cases, the difference is fully one-third.

When a beam is of equal thickness throughout its depth, the curve should be an ellipse, to enable it to support a uniform load with equal resistance in every part; and if the beam is an open one, the curve of equilibrium, for a uniform load, should be that of a parabola. Hence, when the middle portion is not wholly removed, the curve should be a compound of an ellipse and a parabola, approaching nearer to the latter as the middle part is decreased.

Girders of Cast Iron, up to a span of 40 feet, are cheaper than of wrought iron.

Cast iron beams and girders should not be loaded to exceed one-fifth of their breaking weight, and when the strain is attended with concussion and vibration, this proportion must be increased, and they should not be subjected to a deflection exceeding the ·05ths of their length, or to a test much exceeding the greatest stress to which they are to be subjected.

Simple cast iron girders may be made 50 feet in length, and the best form is that of Hodgkinson: when subjected to a fixed load, the flanch should be as 1 to 6, and when to a concussion, &c., as 1 to 4.

The forms of girders for spaces exceeding the limit of those of simple cast iron, are various; the principal ones adopted are those of the straight or arched cast iron girders in separate pieces, and bolted together, the trussed, the bow string, and the wrought iron box and tubular.

The *Straight* or *Arched girder* is formed of separate castings, and is entirely dependent upon the bolts of connexion for its strength.

The *Trussed* or *Bow String girder* is made of separate castings on a single piece, and its strength depends, other than upon the depth or area of it, upon the proper adjustment of the tension, or initial strain, upon the wrought iron truss.

The *Box* or *Tubular girders* are made of wrought iron, and are best constructed with cast iron tops, in order the best to resist compression: this form of girder is best adapted to afford lateral stiffness.

Floor Beams, Girders, &c.

The condition of the stress borne by a Floor Beam is that of a beam supported at both ends and uniformly loaded; but from the irregularity in its loading and unloading, and from the necessity of its possessing great rigidity, it is impracticable to estimate its capacity other than as a beam, having the weight borne upon the middle of its length.

To Ascertain the Depth of a Floor Beam, the Length and Breadth being Given.

When the distance between the Centres of the Beam is One Foot.

Rule.—Divide the product of the square of the length in feet and the weight to be borne in pounds per square foot of floor, by the product of four times the breadth and the *value* of the material from the preceding table (page 387), and the square root of the quotient will give the depth of the beam, in inches.

Example.—A white pine beam is 2 inches wide and 12 feet in length between the supports; what should be the depth of it to support a weight of 175 lbs. per square foot?

$$\frac{12^2 \times 175}{2 \times 4 \times 30} = 105, \quad \text{and } \sqrt{105} = 10{\cdot}25 \textit{ ins.}$$

When the Distance between the Centres of the Beam is greater or less than one foot.

Rule.—Divide the product of the square of the depth for a beam, *when the distance between the centres is one foot*, by the distance given in inches by 12, and the square root of the quotient will give the depth of the beam in inches.

Example.—Assume the beam in the preceding case to be set 15 inches from the centres of its adjoining beams; what should be its depth?

$$\frac{10{\cdot}25^2 \times 15}{12} = 131{\cdot}25, \quad \text{and } \sqrt{131{\cdot}25} = 11{\cdot}45 \textit{ ins.}$$

Headers and Trimmer Beams.—The conditions of the stress borne or to be provided for by them, in floors, are as follows:

Headers or Trimmers—Support one-half of the weight of and upon the tail beams inserted into or attached to them.

Trimmer Beams—Support, in addition to that borne by them directly as a floor beam, each one-half the weight on the headers.

Hence, The stress on a header is due directly to its length, or the number of tail beams it supports; and the stress on the trimmer beams is due to the half of the weight on the header supported by them.

NOTE.—The distance between the support of the trimmer beams and the point of connexion with the header, does not in any wise affect the stress on the trimmer beams; for in just proportion as this distance is increased, and the stress upon them consequently increased by the suspension of the header from them nearer to the middle of their length, so is the area of the surface supported by the header reduced, and, consequently, the load to be borne by it.

Girder.—The condition of the stress borne by a Girder is that of a beam fixed or supported at both ends, as the case may be, supporting the weight borne by all of the beams resting thereon, at the points at which they rest; and its dimensions must be proportionate to the stress upon it, and the distance between its points of insertion or support.

ILLUSTRATION.—It is required to determine the dimensions of a pitch pine girder, 15 feet between its several points of supports,* to support the ends of two lengths of beams each 20 feet in length, having a superincumbent weight, including that of the beams, of 200 pounds per square foot.

The condition of the stress upon such a girder would be that of a number of beams, 40 feet in length (20×2), supporting at both ends and loaded uniformly along their length, with 200 lbs. upon every superficial foot of their area.

Hence, The amount of the weight to be borne is determined by $20 \times 2 \times 15 \times 200 = 120{,}000$ *lbs.* = *the product of twice the length of a beam, the distance between the supports of the girder and the weight borne per square foot of area*, and the resistance to be provided for is that to be borne by a beam, 15 feet in length, fixed at both ends, and supporting 120,000 lbs. uniformly laid along its length, equal to 60,000 lbs. supported at its centre.

Consequently, $\frac{15 \times 60{,}000}{6 \times 50} = 3000 =$ *quotient of the product of the length and weight ÷ the product of 6 times the Value of the material;* and assuming the girder to be 12 inches wide, then,

$$\sqrt{\frac{3000}{12}} = 15{\cdot}8 \text{ } \textit{ins., the depth required.}$$

(To be Continued.)

Professor Way's Electric Light.

From the Lond. Engineer, No. 245.

The passengers over the Hungerford Suspension Bridge, and on the Lambeth strand, on Monday evening last, were enabled to witness the effect of the electric light invented by Professor Way; the brilliant flood from which issued from a window on the north side of the river, bringing into startling relief every object it encountered. This light differs in character from that produced through electrical agency by

*When a girder has four or more supports, its condition is that of a beam fixed at the ends.

means of charcoal points, and from the lime-light, principally in its great volume, appearing, not as a single vivid point, but as a focus of considerable dimensions. It is of an intense white color, with a tinge of green. The effect of its intermission was very striking; the glare of broad daylight being suddenly exchanged for darkness, rendered visible by the moon looking unusually dim and red by the effect of the contrast. Proceeding to the *locale* whence issued the illumination, the arrangements were kindly explained by Mr. Thomas Evans, who had charge of the apparatus, and subsequently by the Professor himself, and we are thus enabled to afford our readers some information respecting the arrangements for producing this light, concerning which little is generally known. A fine stream of mercury, which can be regulated according to the battery power and the volume of light required, passes from an upper into a lower reservoir, and is made to conduct the electric current, by means of which it becomes intensely heated and partly dissipated in vapor. The vaporized mercury becomes subsequently condensed, and proceeds to the lower reservoir, whence it again issues, when the upper reservoir is exhausted and the apparatus reversed. The evolution of light by the passage of the electricity through the fluid conductor appears, however, to be due, not alone to the heating effect, but also, as in the case of the light from charcoal points, to the intensity of the current employed. This fact, which is of interest in explaining the phenomenon which takes place, was pointed out to us by Mr. Fuller, the electrician of the Silvertown Telegraph Cable Works, and was confirmed by an examination of the battery employed, which, contrary to our anticipation, was an *intensity* rather than a *quantity*, or heating arrangement. The employment of the mercury stream, as a conductor, fulfils conditions which would probably be wanting in any other substance which could be used for the purpose of obtaining light by similar means. Thus, although some illuminating effect may be produced by heating platinum wire to whiteness by a quantity current, this conductor is deficient in those characters which enable us, by means of tension electricity, to obtain light from charcoal points, interrupted metallic conductors, and the mercury stream of Professor Way. If, on the other hand, we interrupt the wire, we obtain the electric spark which appears in making and breaking contact with mercury; but we fail to produce the heating effect upon the conductor, to which the illuminating power is partly due in the arrangement under notice. It is obvious, moreover, that the constant renewal of the conductor renders it possible to employ a current of any degree of power, and which would be otherwise inadmissible. The vertical mercury stream must be considered as composed of a multitude of conducting globules separated by an imperceptible interval, and thus affording the vivid spark which occurs in making and breaking contact with the metal. This hypothesis affords an explanation of the fact, that an equal illuminating effect cannot be obtained with a *horizontal* stream of mercury, although the latter may be heated to an equal degree. It should be observed, that the apparatus of Prof. Way, which may probably before long be employed in light-houses and

for signalling, is rendered air-tight, so as to preclude the possibility of any injurious effect arising from escape of the vaporized mercury.

Translated for the Journal of the Franklin Institute.

Note relative to the Mathematical Expression for the Mechanical Equivalent of Heat. By M. DESPRELS, Major of 11th regiment of Artillery.—*L'Institut*, October, 1860.

A dynamic theory of heat according to the ideas of Mongolfier as to the identity of heat and motion, tends to cause this agent to be considered as the expression of the movement of particles of common matter; the moving force or work of which, is capable of being communicated, while being reduced, as the velocity of a fall of water is reduced or even destroyed, after having communicated to the hydraulic machine an amount of work equal to one-half of the moving force which has disappeared.

In this theory the mechanical equivalent of heat is defined to be the quantity of work which an unit of heat can thus produce as it disappears, or reciprocally, the quantity of work, which while being apparently destroyed, will produce an unit of heat. The determination of this quantity has been the object of the experiments of various savans and especially of M. Joule, who has estimated its value at 424 kilogrammetres; the heat necessary to raise 1 kilogramme of water from 0° to 1°, being taken as unity.*

I hoped to reach an analytical expression for this quantity, by reasoning in the following way:

Let us consider any elastic fluid at the temperature 0°.

Let us establish the following notations:

E = the mechanical equivalent of 1 calory in kilogrammetres.

a = the co-efficient of dilatation of the fluid under consideration.

P = the pressure in kilogrammes, of the fluid upon 1 metre square.

δ = the weight in kilogrammes, of a cubic metre of the fluid.

c = the quantity of heat necessary to raise 1 kilogramme of the fluid from 0° to 1°; the pressure remaining constant.

c' = the quantity of heat necessary to raise 1 kilogramme of the fluid from 0° to 1°; the volume remaining constant.

$k = \frac{c}{c'}$ = the ratio of these preceding quantities.

Let us consider 1 kilogramme of this fluid enclosed in a cylinder of a pump which is a non-conductor of heat; having for its base $\frac{1}{\delta}$, and therefore, for its height, 1 metre, from the bottom of the cylinder to the piston.

If we raise the temperature of the fluid 1°, without changing the pressure P, it will dilate, and (neglecting the friction) the piston will move through a space = a. The work thus done will evidently be equal to $\frac{P\,a}{\delta}$.

* The quantities used in this article are all expressed in French measures, and in Centigrade degrees.

This rise of the temperature has been produced by the heat c; this same quantity of heat divided by k, would have been sufficient to have raised the temperature of the fluid 1°, if the piston had been unmoved, that is if there had been no production of work. Moreover, in either case, although the pressures are different, the fluid at 1° contains the same quantity of heat $\frac{c}{k}$ above that which it had at 0°. In fact it would always be easy to bring it from one pressure to the other without for a single instant changing the quantity of heat which it contains; for this purpose it would be sufficient to dilate or compress it, adding or withdrawing every instant, quantities of heat having for their equivalents, the successive differential elements of the work due to the dilatation or compression. Such additions or subtractions would not at all change the quantity of heat before contained in the fluid, since they would just compensate the heat which disappeared or was produced, by the effect of the dilatation or compression.

The production of work, which has been shewn in raising the temperature of the fluid one degree, has therefore been accompanied by a loss of heat represented by $c - \frac{c}{k}$; a quantity whose mechanical equivalent is the work $\frac{P a}{\delta}$. The equivalent (E) of one *calory* will then be represented by the expression

$$E = \frac{\frac{P a}{\delta}}{c - \frac{c}{k}} = \frac{P a k}{\delta c (k - 1)} \qquad (a)$$

The co-efficient k is unknown, but it may be deduced from the value of another co-efficient from which it differs very little. This other co-efficient, which I shall designate by k', when diminished by unity, represents the increase or depression of temperature of a fluid mass at $t°$, by the effect of a compression or dilatation of its volume equal to $\frac{a}{1 + a t}$. It enters as a factor into the equation which represents the velocity of sound in a fluid $v = \sqrt{g h \frac{\Delta}{\delta} k' (1 + a t)}$; in which g represents gravity, h the height of the mercurial barometer, $\frac{\Delta}{\delta}$ the ratio of the densities of mercury and the fluid. The value of k' may thus be easily determined by the measurement of the velocity of sound in the fluid; it was thus directly determined, but for air only, by an experiment of Clement and Desormes.

The signification of the co-efficient k' may be determined in another way. In fact, if we heat through k' degrees, under constant volume, a fluid mass at $t°$, its temperature will become $(t + k')°$, and its pres-

sure will be increased; if we then dilate it by a fraction of its volume $= \frac{a}{1 + a t}$, it will, from the definition of k', undergo a cooling equal to $k' - 1$, and its temperature becoming $t + 1$ will correspond then to its primitive pressure. It may therefore be said, that k' represents the number of degrees by which the temperature of a fluid must be increased, under constant volume, in order that when it afterwards expands to its primitive pressure, this increase of temperature shall be reduced from k' to 1°.

When the fluid mass is 1 kilogramme, its specific heat c under constant pressure is necessarily a little less than the quantity of heat $c' k' = c \frac{k'}{k}$ necessary to raise its temperature 1°, in the method indicated; a method which evidently implies a greater quantity of work done.* Let us endeavor to express the value of this work, in order to deduce from it the value of k.

Let us as before, suppose 1 kilogramme of fluid at 0°, enclosed in a cylinder whose section $= \frac{1}{\delta}$ with a height of 1 metre. Increase the temperature of this fluid by k' degrees, under constant volume, and then let it fall from k' to 1°, by a dilatation a.

Let x be a variable quantity between 1 and $1 + a$, representing the distance of the piston from the bottom of the cylinder during the expansion.

Let $t°$ be the temperature of the fluid corresponding to the distance x and variable from k' to 1.

The work done by the expansion will evidently be

$$\frac{\mathrm{P}\, a}{\delta} \int_{x=1}^{x=1+a} \frac{1 + a t}{x} dx.$$

The variable x being comprehended between the very narrow limits 1 and $1 + a$, the expression under the integral sign may be replaced by the mean of its extreme values $\left(1 + a \frac{k'}{2}\right) dx$. The work done will then be $\frac{\mathrm{P}\, a}{\delta}\left(1 + a \frac{k'}{2}\right)$.

* The error which was formerly committed in the interpretation of the experiment referred to, and consequently in the signification of the co-efficient adopted to modify the formula by which Newton had expressed the velocity of sound, through a fluid, consists in the confounding (which was at that time inevitable) of the quantities of heat c and $c \frac{k'}{k}$. This error cannot be in the equality of the specific heats under constant pressure, and under constant volume; for if it is, as I have above shewn, correct to say that the heat *contained* in the same fluid mass raised from 0° to 1° under constant pressure and under constant volume, is the same; yet it is equally true to add that the heat *received*, that is to say necessary to produce similar effects, are essentially different. It is in this latter sense that I have defined c and c'. The error of the interpretation of the experiment exists therefore not in the words only but in fact. In fact k and k', quantities nearly equal but theoretically different, have been confounded: k represents $\frac{c}{c'}$, and k' may be put under the form $\frac{c''}{c'}$; c'' representing the heat which it is necessary to give, under constant volume, to 1 kilogramme of an elastic fluid at 0°; in order that, in afterwards expanding to its primitive pressure, that is by a fraction a of its volume, its temperature may be carried from 0° to 1°.

This is evidently a little greater than the work $\frac{\text{P}\,a}{\delta}$ which accompanies the action of the specific heat under constant pressure.

Dividing this work by the loss of heat $= \frac{c}{k}(k' - 1)$ which it caused, the mechanical equivalent of a calory will again be obtained.

Referring then to the equation (a) we shall have:

$$\frac{\frac{\text{P}\,a}{\delta}\left(1 + a\frac{k'}{2}\right)}{\frac{c}{k}(k' - 1)} = \frac{\text{P}\,a\,k}{\delta\,c\,(k - 1)}$$

when we conclude $$k - 1 = \frac{k' - 1}{1 + \frac{a\,k'}{2}} \qquad (a)$$

and consequently $$\text{E} = \frac{\text{P}\,a\,k'\left(1 + \frac{a}{2}\right)}{\delta\,c\,(k' - 1)} \qquad (b)$$

If I apply this formula to the atmospheric air, assuming the velocity of sound at 0° equal to 333 metres, and assuming with M. Regnault, for the co-efficient of dilatation, the specific heat and the weight of air and of mercury, the following numbers,

$$a = 0{\cdot}00367\,;\ c = 0{\cdot}23741\,;\ \delta = 1{\cdot}293187\,;\ \Delta = 13595{\cdot}93 = \frac{\text{P}}{0{\cdot}76},$$

I obtain, $k' = 1{\cdot}41485$. $\text{E} = 422{\cdot}03$ kilogrammetres.

This value of the mechanical equivalent of heat does not differ by a very notable quantity from the results of direct experiments, which appear to be grouped around the value 424 kilogrammetres.

The formula (b) moreover must give a value of this quantity affected by slight inaccuracies which may yet affect the determination of its factors. It appears to establish a natural connexion between these various quantities destined to control each other, and mutually to rectify each other, by means of the experiments, of which each one of them may have been or may become the object.

The correctness of the number adopted for the velocity of sound especially, exercises a preponderating influence on the precision of the value of the mechanical equivalent. Thus by admitting, in accordance with an experiment of MM. Bravais and Martins, the number 332·37 m. in place of 332 m. for the velocity of sound at 0°, we obtain 425·92 in place of 422·03 kilogrammetres for the mechanical equivalent of heat.

The following table gives the values of the mechanical equivalent of heat (E) deduced from the formula (b) applied to various gases, assuming for k' the values generally admitted, and for δ, c and a the results of the experiments of M. Regnault.

Gas.	a.	δ.	c.	k'.	E.
Air, . .	0·00367	1·293187	0·23741	1·421	417·67
Oxygen, .	0·00367	1·429802	0·21751	1·415	416·54
Hydrogen, .	0·003661	0·089578	3.4090	1·407	429·03
Carbonic Acid,	0·00371	1·977414	0·20246	1·338	379·75

Deducing directly the values of k' from the velocities of sound (v) in these different gases, I obtained other results as below:

	Air.	Oxygen.	Hydrogen.	Carbonic acid.
Values of v, .	333·	317·17	1269·50	261·60
" k', .	1·41485	1·419128	1·424393	1·32980
" E, .	422·03	412·69	416·24	387·66

The reasoning which led to the formulæ (a) and (b) would be exactly applicable to a fluid passing from the temperature t to the temperature $(t + 1)$. For that purpose it will be sufficient for gases, under the law of Mariotte, to replace a by $\frac{a}{1 + at}$. If the gas considered, departs from this law, it would be necessary to replace a by another notation a_t, which should represent the increase of volume of the fluid passing from $t°$ to $(t + 1)°$ without change of pressure. We should thus obtain more general expressions, capable of connecting together the variations of their consecutive factors for the variations of temperature.

The considerations on which all these formulæ rest, assume that the heat which has disappeared has all been converted into mechanical work. But it may happen otherwise, and nothing opposes our admitting that in certain cases a portion of the heat is absorbed in molecular work not capable of being at once transformed into mechanical work. In such a case the formula (b) could no longer represent the absolute invariable value of the equivalent of heat but only the value of an equivalent dependent on the medium through which the heat acts. Recent experiments of M. Regnault (as yet, I believe, unpublished) seem to indicate that this is the case with gases near their points of liquefaction, and that the value of the equivalent may in such a case vary by nearly $\frac{1}{8}$ of its value in gases of a more permanent character. It is undoubtedly to causes of this kind that we must attribute the low values of E, in carbonic acid, a liquefiable gas. I regret that I have not been able to obtain data sufficient for the application of my formula to other gases near their point of liquefaction.

The formula (a) by determining the quantity k, permits us to calculate the quantity of heat which a gas contains at a certain temperature; it also gives us the means of calculating the quantity of heat absorbed by a fluid heated through $t°$, when both its volume and pressure change.

This problem is indeterminate;* but in each particular case, it is susceptible of a solution expressed in a function of the mechanical equivalent of heat.

Let us conceive a vertical cylinder of 1 square metre in base, containing in its lower part, whose height is L, a weight Q of an elastic fluid at the temperature θ, and in its upper part, whose height is H, a weight of water equal to 1000 H; these two parts being separated by a piston, whose weight, thickness, and friction, I will neglect. Suppose this cylinder to be surmounted by a vessel whose height is H', open at its two extremities and capable of holding the volume of water assumed above. Let us heat the fluid, permitting it to expand freely under the variable pressure which it supports, so that when its temperature shall be $t°$, it occupies the whole capacity of the cylinder, having driven out all the water into the upper vessel. Let h be the distance of the centres of gravity G and G' of the water in its extreme positions, in the cylinder and in the vessel.

The pressure of the elastic fluid at the beginning of the motion is necessarily supposed equal to the atmospheric pressure (P) increased by 1000 H. When the piston has reached the end of its course, at the top of the cylinder, this pressure will be equal to $P + 1000\,H'$, the height H' being invariably determined in a function of t, from the equation,

$$\frac{L\,(1+a)\,(\theta+t)\,(P+1000\,H)}{(1+a\,\theta)\,(P+1000\,H')} = L + H.$$

The work done, when the liquid has all passed into the upper vessel, will be $= P\,H + 1000\,H\,h$; and the heat which has disappeared, in the production of this work, will be evidently equal to

$$\frac{1}{E}\,(P\,H + 1000\,H\,h).$$

E representing the mechanical equivalent of the heat, absolute or relative according to the nature of the fluid; as in formula (b).

On the other hand the fluid at the temperature $(\theta + t)°$, contains, in addition to that which it had at the temperature $\theta°$, a quantity of heat $= \frac{Q\,c\,t}{k}$, which, according to the formula $(a) = \frac{Q\,c\,t\left(1 + k'\,\frac{a}{2}\right)}{k'\left(1 + \frac{a}{2}\right)}$

The whole quantity of heat received by the fluid will then be $=$

$$\frac{Q\,c\,t\left(1 + k'\,\frac{a}{2}\right)}{k'\left(1 + \frac{a}{2}\right)} + \frac{1}{E}\,(P\,H + 1000\,H\,h).$$

This equation is indeterminate, for without changing either the heat

* My attention was called to this problem by reading the following passage in the "*Cours de Physique de l'Ecole Polytechnique*" by M. Jamin, Vol. 2d, page 355.

"It would moreover be necessary, that we should be able to calculate the heat absorbed when a weight P of a gas is heated through r°, its volume and pressure both changing. These are questions of which recent investigations have shewn the complexity, and which have not yet been solved.

or the expansion of the gas, and consequently without changing the level of the liquid after its ascent, we may, by changing the form of the vessel, vary the position of the centre of gravity of the liquid raised, the work to be done, and therefore the heat which will disappear. In each particular case it must be solved by dividing the integral of the elementary works done, by the mechanical equivalent of heat, absolute or relative according to the nature of the fluid, and adding to this fraction the excess of heat which the fluid really contains in consequence of its heating.

For the Journal of the Franklin Institute.

Particulars of the Clipper Ship Garibaldi.

Hull built by Messrs Maxson, Fish & Co., Mystic, Conn. Owners, Messrs. Calvin Adams & Co., City of New York. Commander, Capt. Edward Adams. Intended service, from New York to Liverpool.

HULL.—Length of keel, 178 ft. Do. of main deck, 193 ft. Do. over all, 200 ft. Breadth of beam at midship section, 40 ft. Depth of lower hold, 14 ft. Do. between decks, 9 ft. Do. of poop deck, 6 ft. 8 ins. Do. of half deck, from poop forward, 4 ft. 8 ins. Keel, 15 × 24 ins. Floors, molded, 17 ins. Very heavy frame, two-thirds white oak, and one-third white chestnut. Bottom planks, 4 inches thick; side do. 5 ins. thick; all of oak. Keelsons, 5 ft. high, of yellow pine. Bilge streaks, 12 ins., diminishing to 10 ins.; at top, 11 ins. Hanging knees (oak), 12 ins. amidship, but diminishing to 8 ins. Five heavy hooks and pointers forward, and three aft, in lower hold. Lower deck beams, 15 × 24 ins. Main deck beams, 15 × 11 ins. Patent windlass for 2 in. chain. Tonnage, 1195 tons.

MASTS.—Foremast, 33 ins. diameter, 77 ft. long; main do., 34 ins. do., 79½ ft. do.; mizen do., 26 ins. do., 73 ft. do. Fore-topmast, main do., topgallant, and royal masts, each 16 ins. diameter, 45 ft. long. Bowsprit, 28 ins. diameter.

YARDS.—Lower yards, topsail do., topgallant do., royal do., each 16 ins. diameter, 45 ft. long.

Distance from knightheads to centre of foremast, 42 ft.; from thence to centre of mainmast, 64 ft.; do. do. mizenmast, 48 ft.; do. taffrail, 45 ft. Rudder-stock, 18 ins. diameter. Pumps, 4—2 of 7½ ins., and 2 of 6 ins.

Remarks.—The materials used in the construction of this vessel were of superior quality, and the manner in which they were put together betokens excellent workmanship. She is thoroughly fastened with copper, leads, cased treenails, &c., &c., and has Long Island locust driven through and wedged inside, from keel to top. The ceiling, in addition to this, is square fastened with bolts.

Immediately after launching, the *Gairbaldi* entered the port of New York, and was there the subject of general remark among sea-cnptains, ship-owners, and others, to the effect, that the beauty of her model, the staunch and sea-worthy appearance she presented, with the superior manner in which she was finished, could not be easily excelled in a vessel of her class. Credit is justly due to Messrs. Maxson, Fish & Co., for such a successful production. E. B.

For the Journal of the Franklin Institute.

Particulars of the U. S. Steam Sloop-of-war Richmond.

The *Richmond* is one of the *five sloops* ordered by Congress, and is of the same class with the *Hartford*, *Lancaster*, and *Brooklyn*.

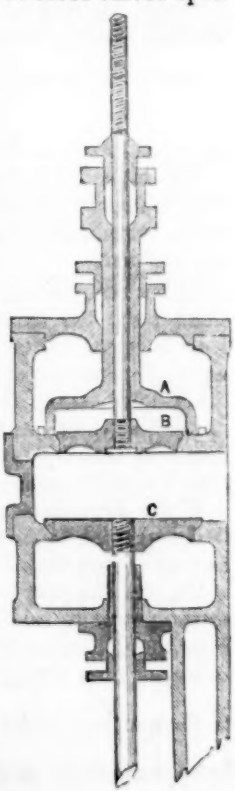
The hull was constructed in the Gosport Navy Yard by the late Samuel T. Hartt. The following are the principal dimensions:

HULL.—Length between perpendiculars, 235 ft. Do. from billet to taffrail, 259 ft. Do. for tonnage, 243 ft. Depth of hold, 12 ft. 8 ins. Draft of water, 15 ft. 6 ins. Tonnage, 2023 91-95 tons. Area of immersed section, 557 sq. ft. Displacement at 15 ft., 2382 tons. Do. at 17 ft., 2829 tons. Length of engine and boiler space, 71 ft.

The machinery was also constructed in the Gosport Yard from the designs of Samuel Archbold, Engineer-in-chief, U. S. Navy, and consists of two horizontal back-acting engines.

Diameter of cylinder, 4 ft. 10 ins. Length of stroke, 3 ft. Diameter of air pump, 19 ins. Do. of crank shaft, 12½ ins. Do. of screw shaft, 12 ins. Maximum pressure of steam, 25 lbs. Do revolutions, 45.

The engines are fitted with a peculiar arrangement of valves connected with Sickle's improved "cut-off." There are three valves upon each end of the cylinder as shown in the annexed diagram. The main steam valve A is made in a cup-form to allow the cut-off valve B to rise whilst the valve A remains in its seat; thus permitting the cut-off valve to be set considerably in advance of the steam valve. C is the exhaust valve. As the valves are now set, the main valve has about $\frac{9}{16}$, the cut-off valve $1\frac{1}{8}$, and the exhaust valve 2 inches lead. The valves are operated by a species of link-motion, so arranged that when the link is in mid position both rock-shaft pins are disconnected and the valves closely seated. This apparatus works very well, but the quantity of machinery required, the complication, and number of moving parts, afford a very serious objection and detract very much from the practical value of an adjustable cut-off.



The cylinders are fitted with steam jackets. The main brasses are chambered to admit a continuous stream of water passing through without coming in contact with the journals.

The crank and screw shafts are coupled with a wrought iron universal coupling, which will allow considerable deviation of the shaft from a straight line without affecting the engines. The screw shaft is fitted with both the collar and cone thrust bearings, and that part of the shaft passing through the dead-wood is cased with brass, and works upon lignum vitæ bushings.

BOILERS.—Three of Martin's vertical tubular boilers. One of these constitutes the "donkey," and consists of a single furnace, but which may be used at any time in connexion with the main boilers.

Length of boilers, 10 ft. 8 ins. Breadth of do., 21 ft. 6 ins. Height of do., exclusive of steam chimney, 10 ft. 9 ins. Do., inclusive of do., 12 ft. 9 ins. Total number of furnaces, 13. Width of do., 3 ft. Length of grates, 6 ft. 6 ins. Total number of tubes, 3900. Length of do., 2 ft. 8 ins. External diameter of do., 2 ins. Total grate surface, 253 sq. ft. Total heating do., 7272 sq. ft. Diameter of smoke pipe, 6 ft. 6 ins. Height of do. above grates, 50 ft. Area of do., 33·18 sq. ft. Least area between tubes, 46·22 sq. ft.

SCREW.—Brass.—Diameter of screw, 14 ft. Length of do., 3 ft. 6 ins. Pitch of do., 25 ft., expanding to 28 ft. Number of blades, two. Weight, 11,820 lbs.

The forward edge of the screw near the periphery is considerably cut away, whilst the after edge is nearly square.

Armament.—Sixteen 9-inch shell guns; total weight of battery 145,155 lbs. or 64·8 tons; two 12-pounder boat howitzers.

Performance.—The run from Gibraltar to Spezzia, Sardinia, a distance per log of 909 miles, was made in four days and three hours—making an average of 9 knots per hour. Under steam alone 8 knots, but with steam and sail, with a moderate breeze, 11 to 11·5 knots. Average number of revolutions per minute, 42, and 15 lbs. of steam with an average consumption of 1920 lbs. of coal per hour.

J. H. W.

For the Journal of the Franklin Institute.

Transverse Strain of Materials.

The object of the present investigation is to demonstrate a mode of experiment by which the relative powers of any flexible material to resist compression and extension by transverse strain, may be exactly ascertained.

Take two prisms of the same material, of equal length, and let them have the same cross section, viz: an isosceles triangle, whose base is equal to its altitude; and having placed them on supports equal distances apart, the one with the vertex of the triangle up, the other down,—note exactly the amount of deflection which equal weights applied at their centres will produce in each: if the deflections produced in each by equal loads are equal, then the powers of the material to resist compression and extension will be equal, under that load.

If the deflections vary, then the power of resistance to compression is the greater when the deflection of the prism loaded with its vertical line up is less than for the one with its base uppermost, and *vice versa*.

To find the proportion which the power to resist compression bears to the power to resist extension, when the former is the greater: let a be the deflection when the base is up, and a_1 the deflection when it is down; then divide a_1 by a, and seek for the number corresponding to the quotient in the column headed $\frac{a_1}{a}$ of the following table; directly opposite to it, in the column headed x, will be found the number

corresponding to the ratio, which the power to resist compression bears to the power to resist extension, for that load.

x	$\frac{a_1}{a}$	x	$\frac{a_1}{a}$	x	$\frac{a_1}{a}$
1·	1·	3·	·8694	5	·81873
1·2	·9804	2·4	·9073	5	·8347
1·4	·9626	2·6			
1·6	·949	2·8	·8910		
1·8	·936	3·	·8845	6	·8258
2·	·9140	4·	·8385	6	·8100

NOTE.—This table can be made out for every 1-10th without much trouble. Before using it, it should be verified and so extended.

For example, let two prisms with equal loads give

With vertical line of pressure up a and

With do do down a_1

for their deflections, and let $\frac{a_1}{a} = ·949$; then the power of resistance of their material to compression, is 1·6 times their power of resistance to extension.

But should a prove less than a_1, and suppose $\frac{a}{a_1} = ·949$; then the power of the material to resist extension would be 1·6 times its power to resist compression.

To explain the manner in which the column $\frac{a_1}{a}$ may be obtained.

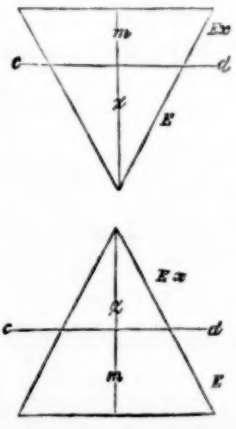
Let the triangles represent the cross sections of the two prisms.

Let h = their altitude = their base.

z and z_1 = the distances from the vertices to $c\ d$.

m and m_1 = the distances from the bases to $c\ d$.

x = the ratio which the power to resist compression bears to the power to resist extension.



The line $c\ d$ being the dividing line between the part of the triangle compressed and the part extended.

Let E = the modulus of elasticity of the material to resist extension,

and Ex = the modulus of elasticity to resist compression—taking the modulus of elasticity in the sense that Weisbach does in his Mechanics, vol. i, chap. 6.

Now, as the basis of the whole we have,

$$\int (h - m - z)\, z^2\, dz = \int (z + m)\, m^2\, dm.$$

From this we obtain the moments of flexure.

(A) $\left(\left(\frac{h z^3}{3} - \frac{m z^3}{3} - \frac{z^4}{4} \right) + \left(\frac{z m^3}{3} + \frac{m^4}{4} \right) x \right) E$, where the vertex is down, and

(B) $\left(x \left(\frac{h z_i^3}{3} - \frac{m z_i^3}{3} - \frac{z^4}{4} \right) + \left(\frac{z m_i^3}{3} + \frac{m_i^4}{4} \right) \right) E$, where the vertex is up.

And we have also the equations,

(1) $$E \left(\frac{h z^3}{3} - \frac{m z^3}{3} - \frac{z^4}{4} \right) = \left(\frac{z m^3}{3} + \frac{m^4}{4} \right) Ex, \quad \text{and}$$

(2) $$Ex \left(\frac{h z_i^3}{3} - \frac{m_i z_i^3}{3} - \frac{z_i^4}{4} \right) = \left(\frac{z_i m_i^3}{3} + \frac{m_i^4}{4} \right) E.$$

Making $h =$ unity, we find from these two equations,

(3) $$z^4 - \frac{6 z^2 x}{x+1} + \frac{8 z x}{x+1} - \frac{3 x}{x+1} = 0, \quad \text{and}$$

(4) $$z^4 - \frac{6 z_i^2}{x+1} + \frac{8 z_i}{x+1} - \frac{3}{x+1} = 0.$$

Now, from equations (3) and (4), by giving to x the successive values 1·2, 1·4, 1·6, &c., we can find the corresponding values of z and z_i.

Now, by taking from Weisbach as before, § 190, the equation $a = \frac{P l^3}{8 W E}$.

Next, from the moments of flexure (A) and (B), we have

$$W = \frac{z^4}{12} + \left(\frac{z}{3} + \frac{m}{4} \right) m^3 x = \frac{z^4}{6}, \quad \text{and}$$

$$W_i = x \frac{z_i^4}{12} + \left(\frac{z_i}{3} + \frac{m_i}{4} \right) m_i^3 = \frac{z_i^4 x}{6}.$$

From these data, the E equation,

$$\frac{z^4}{x z_i^4} = \frac{a_i}{a},$$

is at once found, and

$$E = \frac{3 P l^3}{8 z^3 a} = \frac{3 P l^3}{8 z_i^3 a_i x}.$$

The suitable dimensions for samples to be experimented on, are

probably from four to six feet long for a cross section of 7 inch base to the triangle.

In making experiments on a pair of samples, the following was the mode of recording the deflections adopted:

Name of Material.	Deflections in inches produced by the weights marked at the head of each column.										
	lbs. 7½.	lbs. 12.	lbs. 16½.	lbs. 21.	lbs. 25½.	lbs. 30.	lbs. 34½.	lbs. 39.	lbs. 43½.	lbs. 48.	lbs. 52½.
Spruce, △		·06	·07	·10	·12	·13	·16	·18	·21	·23	·24
do, ▽		·06	·09	·11	·13	·17	·19	·22	·25	·28	·30

The apparatus used in these experiments was too clumsy to afford satisfactory results, and their lengths compared with their cross sections were too short: they were 2 feet long, and had 1 inch for the base of their triangle.

Translated for the Journal of the Franklin Institute.

Method of Disinfecting Mouldy Casks. By M. Chetelain.

The casks are first washed out for about five minutes with an alkaline solution of soda, and are then soaked for one or two days with a liquor acidulated with hydrochloric acid.

The Committee of the Society for the Encouragement of National Industry report that the process is effective both for wine and beer casks; that it is cheap; and saves great expense.—*Bull. Soc. Encour. l'Indust. Nat.*, May, 1860.

AMERICAN PATENTS.

AMERICAN PATENTS ISSUED FROM NOVEMBER 1, TO NOVEMBER 30, 1860.

Air Engines,	Stephen Wilcox, Jr.,	Westerly,	R. I.	20
———	"	"	"	20
Amalgamator,	Woodworth & Wethered,	San Francisco,	Cal.	27
———	Wyckoff & Fell,	Brooklyn,	N. Y.	27
Apple and Potato Parer,	Clewell, Jr., & Schatz,	Nazareth,	Penna.	20
Aural Instruments,	C. G. Page,	Washington,	D. C.	20
Baby-jumper, couch, & carriage,	J. S. Brown,	Green Point,	N. Y.	27
Bed Bottom,—Spring	Rosenberg & Scheuerle,	City of	"	13
Blind Fastenings,	J. J. Henry,	N. White Creek,	"	27
———	Wm. S. Kirkham,	Brantford,	Conn.	6
Blowpipe Operations,—Supports	J. B. Hyde,	Newark,	N. J.	20
Boat into a Land Carriage,	Perry Davis,	Providence,	R. I.	13

Bobbins,—Friction Brakes for	Truman Estes,	N. Bennington,	Vt.	27
Bridges,—Truss	J. L. Jones,	St. Louis,	Mo.	6
Brush-making Machine,	John Ruegg,	"	"	20
Burners,—Hydro-carbon,	M. L. Collender,	City of	N. Y.	20
Burnishing Machines,	A. M. White,	Hartford,	Conn.	20
Calligraphs,	Charles Thurber,	Brooklyn,	N. Y.	27
Canal and River Locks,	James Davies,	Schuylkill Nav.	Penna.	6
——— Navigation,—Chutes for	Alonzo Livermore,	Tremont,	"	27
Candles,—Moulding	Thomas King,	Troy,	N. Y.	6
Caoutchouc,—Vulcanization of	F. D. Hayward,	Malden,	Mass.	27
Carpenters Clamp,	C. L. Jones,	Richmond,	Va.	27
Carpet Duster,	Joseph Rolls,	City of	N. Y.	6
Carriages,—Detaching Horses	John Davis,	Elmira,	"	6
Cartridge Cases,—Forming	Christian Sharps,	Philadelphia,	Penna.	13
Chain Link,	J. P. Kirk,	Austin,	Texas,	13
Cheese,—Manufacture of	Wm. McAllister,	Gerry,	N. Y.	13
Churns,	Nevers & Ross,	Claremont,	N. H.	20
Clevis,	Frederick Sigrist,	Napa co.,	Cal.	27
Clocks,	Wm. B. Barnes,	Forestville,	Conn.	6
Clothes Sprinkler,	S. N. Davies,	Muskegon,	Mich.	6
——— Squeezer,	G. D. Trumpore,	Newark,	N. J.	6
Clothing,—Spring Hooks for	J. C. Loveland,	Springfield,	Vt.	20
Coffee-pots,	John Beaumont,	Hartford,	Conn.	6
Collar for Horses,—Breast	J. G. Taylor,	Philadelphia,	Penna.	27
Corn Balls,—Moulding Parched	Russell Arnold,	Hartford,	Conn.	20
—— Planters,	W. H. Addle and others,	Norristown,	Penna.	27
———	Benj. Bower,	Millersburg,	Ohio,	27
Cotton and Corn Stalk Cutters,	G. S. Roundebush,	Natchez,	Miss.	13
——— Seed,—Cleaning	A. J. Hardin,	Shelby,	N. C.	6
Cotton Scrapers,	C. H. Burbidge,	Middletown,	Conn.	27
———	Collins & Wilkinson,	Clinton,	La.	27
———	W. L. Milholen,	Centre,	Ala.	27
Coupling,—Hose	B. Holly,	Lockport,	N. Y.	20
———,—Thill	R C. Millings,	Charleston,	S. C.	27
Cracker Machine,	J. and J. C. Holyland,	Rochester,	N. Y.	27
Cultivators,	J. H. and E. H. Anderson,	Easton,	Md.	27
———	L. B. Benton,	Penn Yan,	N. Y.	27
———	C. A. Clark,	Bloomfield,	Iowa,	27
———	H. J. Lake,	Conquest,	N. Y.	27
———	W. J. McCoy,	Cartersville,	Ga.	27
———	Nelson Messenger,	Newark,	Ill.	27
———	Moore & Satterwhite,	Rome,	Ga.	27
———	Neidich & Girvin,	Lancaster co.,	Penna.	27
———	H. C. Ravenscraft,	Kingwood,	Va.	27
———	Robertson & Carr,	Kingston,	Mo.	6
———,—Cotton	Noah Rogers,	Thomas co.,	Ga.	27
———	L. Stevens,	Dover,	Ky.	27
———	H. G. Street,	Liberty,	Miss.	27
Cylinders,—Holding	George Williamson,	Newark,	N. J.	13
Dental Chairs,	V. Van Vleck,	City of	N. Y.	20
Dough,—Raising and Kneading	George Scott,	Steubenville,	Ohio,	27
Drill Frames,	G. C. Taft,	Worcester,	Mass.	27
Edge Tools,—Manufacture of	S. W. Collins,	Canton,	Conn.	20
Electro-plating with Gold Alloys,	Archille Berthoud,	City of	N. Y.	20
Embalming Dead Bodies,	Warren Iddings,	Warren,	Ohio,	6
Excavators,	A. J. Bartlett,	Romulus,	N. Y.	13
———,—Channel	Robert Gamble, Jr.,	Tallahassee,	Fa.	13
Fences,	O. H. Woodworth,	U. Marlborough,	Md.	27
Fire Alarms,	A. F. Cobb,	Chapel Hill,	Mo.	13
———	E. Ehlin,	Boston,	Mass.	13

Fire Arms,—Breech-loading	John Boynton,	E. Hartford,	Conn.	27
———————————	J. S Reeder,	Canton,	Ohio,	27
———,—Revolving	Christian Sharps,	Philadelphia,	Penna.	27
———————	John Adams,	Dalston,	Engl'd,	6
—— Escapes,	E. B. Larchar,	City of	N. Y.	13
———	Hugh Morohan,	Brooklyn,	"	13
Fly Traps,	S. S. Day,	City of	"	13
Flood Fence,	D. C. Wilkinson,	Sidney,	Ohio,	6
Fodder Cutters,	A. R. Reese,	Phillipsburgh,	N. J.	20
Fractured Limbs,—Apparatus for	J. M. Pitts,	Sumter,	S. C.	6
Fruit Jars,—Covers for	T. B. and J. S. Atterbury,	Pittsburgh,	Penna.	20
Furnaces,	C. F. Cory,	Lebanon,	Ill.	27
———,—Hot Air	Joseph Leeds,	Philadelphia,	Penna.	27
———————	Oscar Paddock,	Watertown,	N. Y.	27
Gates,—Farm	G. C. Bovey,	Chillicothe,	Ohio,	27
Glass Cutters,	Collman & Feenders,	Freeport,	Ill.	27
Gold Amalgamator,	A. K. Eaton,	City of	N. Y.	6
——————— and Washer,	J. C. Dickey,	Saratoga Sp'gs,	"	20
Grafting Machines,	J. W. Crawford,	Rockport,	Ind.	13
Grain Cleaning Machines,	Wm. Crotzer,	Spruce Creek,	Penna.	20
—— Separators,	C. B. Hutchings,	Rochester,	N. Y.	20
———————	S. and O. Pettibone,	Corunna,	Mich.	20
Harness Saddle,	T. J. Weeks,	New London,	Conn.	13
Harrows,	James Temple,	Bellefonte,	Penna.	27
———,—Cultivating	Joseph Slocum,	Syracuse,	N. Y.	27
———,—Rotary	Given & Foreman,	Sumner Hill,	Penna.	27
———————	Francis Raymond,	Sandusky,	Ohio,	27
Harvesters,	L. D. Brown,	St. Louis,	Mo.	20
———	Frederick Landon,	Brockport,	N. Y.	13
———	Nathan Maxson,	Wilmington,	Ohio,	13
———	S. W. Tyler,	Greenwich,	N. Y.	13
———,—Cutting Apparat.	W. G. Smith,	Elizabethport,	N. J.	6
Hatchets,	M. E. Rudasill,	Shelby,	N. C.	20
Hats,—Ventilating	Julius Pollock,	Morrisania,	N. Y.	13
Hawse Pipes,	Charles Perley,	City of	"	27
Hay, &c.,—Cutting	T. H. and D. T. Wilson,	Harrisburg,	Penna.	6
—— and Straw Cutters,	H. R. Hawkins,	Akron,	Ohio,	20
Heating Apparatus,	E. L. Brown,	Brooklyn,	N. Y.	27
Heel Shave,	D. E. Somes,	Biddeford,	Me.	13
Hinge,	Adams & Peckover,	Cincinnati,	Ohio,	6
———,—Gate	David Wadsword, Jr.,	Nashua,	N. H.	6
———,—Stop	Henry Pennie,	Buffalo,	N. Y.	6
Hoes,—Making	Moses Depuy,	Pittsburgh,	Penna.	6
Hoop Machines,	S. F. Atherton,	Fitchburg,	Mass.	13
Horse Collars,	Briding & Maxwell,	Baltimore,	Md.	27
——— Shoe Machine,	John McCarty,	Philadelphia,	Penna.	13
——— Shoes,—Punching	C. H. Perkins,	Providence,	R. I.	20
Hose,—India Rubber	T. J. Mayall,	Roxbury,	Mass.	13
Hubs of Carriage Wheels,	James Johnson,	Garysburg,	N. C.	20
Lamps,—Vapor	H. Wm. Dopp,	Buffalo,	N. Y.	13
———————	M. W. Dillingham,	Charlestown,	Mass.	6
———————	C. E. Atherton,	Paterson,	N. J.	6
Last Holder,	John Dickinson,	Painesville,	Ohio,	13
Latches,—Door	Thomas Slaight,	Newark,	N. J.	6
Leather,—Creasing	Wm. S. Bullen,	Indianapolis,	Ind.	27
———,—Cutting	J. W. Richardson,	S. Braintree,	Mass.	27
———,—Skiving	Samuel Keen,	E. Bridgewater,	"	27
Lightning Rods,	N. Brittan,	Lockport,	N. Y.	6
Locks,	Wm. S. Kirkham,	Brantford,	Conn.	6
———	Lewis Layman,	Westfield,	N. Y.	6
———,—Door	Jacob Kinzer,	Pittsburgh,	Penna.	13

Locks,—Door	J. E. Parker,	W. Meriden,	Conn. 6
Looms for Weaving Hair Cloth,	Isaac Angell,	Pawtucket,	R. I. 13
Marine Propeller,	H. D. J. Pratt,	Washington,	D. C. 27
Milking Stool,	Levi Loring,	Saco,	Me. 6
Mousing Hook,	John North,	Middletown,	Conn. 20
Odometers,	L. W. Nicholls,	N. Brookfield,	N. Y. 13
Oils,—Trying	J. M. Hunter,	City of	" 6
Ordnance,	T. J. Mayall,	Roxbury,	Mass. 27
Packing Meats,—Buildings for	D. E. Somes,	Biddeford,	Me. 27
Paper,—Damping	Richard Martin,	Philadelphia,	Penna. 27
——,—Folding	Cyrus Chambers, Jr.,	"	" 27
Pictures,—Prep. of Transparent	Gustav Wedekind,	"	" 13
Pie Crimper,	C. A. Shaw,	Biddeford,	Me. 6
Ploughs,	Andrew Benkelmann,	Langford,	N. Y. 27
——	T. R. Cormick,	Cap-au-gris,	Mo. 27
——	Samuel Fisher,	W. Windsor,	N. J. 27
——	T. S. and J. A. Lockhart,	Wellington,	Mo. 27
——	Matheny & Barnes,	De Kalb,	Miss. 27
——	J. P. Pettit,	Cold Spring,	Ky. 27
——	A. W. L. Rivers,	Midway,	S. C. 27
——,—Cotton	W. W. Graves,	Fort Adams,	Miss. 27
——,—Hillside	R. H. Ewing,	Clives,	Ohio, 27
——,—Mole	J. H. Elward,	Ottawa,	Ill. 13
——	Owen Sturdevant,	Maquon,	" 13
Plough Plates of Molten Steel,	F. F. Smith,	Momence,	" 20
Plumb-bob,	B. F. Chappell,	Norwich,	Conn. 13
Preserve Cans,—Sealing	W. W. Paddock,	Cincinnati,	Ohio, 6
Printing Plates, &c.,—Relief	E. B. Larchar and others,	City of	N. Y. 13
Provisions,—Curing	D. E. Somes,	Biddeford,	Me. 13
Pumps,	Benjamin Douglas,	Middletown,	Conn. 6
Railroad Cars,—Heaters for	Wm. Pauli,	Alexandria,	Va. 27
—— Chairs,—Making	David Eynor,	Philadelphia,	Penna. 20
—— Joints,	J. M. Heard,	Prairie Station,	Miss. 13
—— Rails to Cross Ties,	S. H. Witmer,	Cincinnati,	Ohio, 20
Rakes,—Horse	John Chappel,	Green,	N. Y. 20
Reaping Machines,—Mowing and	Franklin Getz,	Amherst,	" 6
——,—Rakes for	J. R. Byler,	Salisbury,	Penna. 27
Rice,—Cleaning	S. P. Kase,	Danville,	" 20
——,—— and Hulling	H. N. Black,	Philadelphia,	" 13
—— Hullers,	Dyer Green,	Boston,	Mass. 6
Saws,—Hanging Circular	David Eldridge,	Philadelphia,	Penna. 20
Saw Mills,	E. G. Dyer,	Hamilton,	Ohio, 13
Scalpels,	A. G. Shaver,	New Haven,	Conn. 20
Seed Drills,	Hiram Moore,	Brandon,	Wis. 20
——	Arnton Smith,	Girard,	Ill. 27
—— Planters,—Cotton	C. W. McClanahan,	Victoria,	Texas, 27
Seeding Machines,	James Morrison,	Clinton,	Me. 27
——	S. R. Warner,	London,	Ohio, 27
Settee or Chair,	G. L. Buckley,	W. Barnstable,	Mass. 20
Sewing Machines,—Loop Catch	L. P. Collins,	Sacramento,	Cal. 13
——	Frederick Heyer,	Richmond,	Va. 27
——	Rufus Leavitt,	Melrose,	Mass. 13
——	R. S. Payne,	Chicago,	Ill. 13
Ships Boats,—Attaching	R. S. Stubbs,	Claremont,	N. H. 20
—— Sails,	W. A. Sands,	Brooklyn,	N. Y. 20
—— Yards,—Attaching Sails to	John Lewis,	Elizabeth,	N. J. 6
Shoes,—India Rubber Tips for	H. B. Goodyear,	New Haven,	Conn. 20
Shutter Fastener,	Jacob Frick,	Philadelphia,	Penna. 6
Skate Shoe and Foot Check,	J. B. Gibbs,	Boston,	Mass. 13

Slide Valves,	R. C. Bristol,	Chicago,	Ill.	13
Soap Composition,	H. N. Willbur,	Keokuk,	Iowa,	20
———	M. A. Butler,	Mariana,	Fa.	6
Sofa and Bedstead,	Sewell Pearson,	Boston,	Mass.	27
Sounding Apparatuses,	J. B. Van Deusen,	City of	N. Y.	27
Spelling Boxes,	D. F. Dunham,	Brook,	Ind.	13
Spinal Braces,	L. B. Wright,	City of	N. Y.	6
Spoons,—Burnishing	H. M. Jacobs,	Hartford,	Conn.	27
Stone,—Dressing,	M. H. Bacon,	Mystic,	"	6
Stove Grates,	L. W. Harwood,	Troy,	N. Y.	13
———	Isaac Smith,	Albany,	"	27
Stoves,—Cooking	DeWitt C. Farrington,	Lowell,	Mass.	20
———	Huntley & Caven,	Cincinnati,	Ohio,	27
———,—Gas	Isaac Cressman,	Philadelphia,	Penna.	20
Straw Cutters,	Jacob Schuffelin, Jr.,	Tioga,	"	20
———,—Hay and	J. N. Neff,	Strasburg,	"	27
Street-sweeping Machines,	Servetus Longley,	Cincinnati,	Ohio,	13
Swifts,	C. W. Pearson,	Charlestown,	Mass.	13
Table,—Adjustable	O. C. Dodge,	Brooklyn,	N. Y.	20
Tanning,—Apparatus for	J. S. Wheat,	Wheeling,	Va.	6
Teeth,—Artificial	J. W. Moffitt,	Harrisburg,	Penna.	20
Threshing Machines,—Spike for	A. B. Colton,	Athens,	Ga.	6
Tide Wheels,—Flow of water on	J. G. Ross,	City of	N. Y.	6
Trees,—Sustaining	Wm. H. Livingston,	"	"	6
Turning Machines,	George Rugg,	Potsdam,	"	13
Valve Gear of Steam Engines,	J. J. Gwynn,	Plainfield,	N. J.	20
Vapor Burners,	Henry Johnson,	Washington,	D. C.	6
Warming Apparatus,	L. A. Colbert,	Baltimore,	Md.	13
Washing Machines,	C. F. Chambers,	Chambersburg,	Ind.	6
———	Sylvender Ellis,	N. Britain,	Conn.	6
———	A. Seamans,	Bowmansville,	N. Y.	20
Watches,—Winding	N. P. Stratton,	Nashua,	N. H.	27
Water Carts,	Henry Austin,	E. Liberty,	Ohio,	27
Water Closets,—Seats of	G. C. Hinman,	Portageville,	N. Y.	6
——,—Apparatus for Drawing	D. E. Teal,	Norwich,	"	27
—— Elevators and Carriers,	David Johnston,	Eddyville,	Iowa,	13
Waterproof Fabrics,	Louis Simonet,	City of	N. Y.	6
Wells,—Drawing Water from	Elliot Andrus,	Geneva,	"	13
———	G. D. Colton,	Galesburg,	Ill.	13
———	H. F. Phillips,	Seneca Falls,	N. Y.	13
Windlasses,—Capstan	S. P. Patten,	City of	"	6
Wire,—Rolling Steel and Iron	John Wright,	Sheffield,	Engl'd,	27
Wood,—Bundling Kindling	Wm. L. Williams,	City of	N. Y.	27
Wrenches,	Wm. Kearney	Union,	N. J.	6

EXTENSIONS.

Artificial Legs,	B. F. Palmer,	Philadelphia,	Penna.	6
Telegraph,—Bell	Judson & Jackson,	Rochester,	N. Y.	6

ADDITIONAL IMPROVEMENTS.

Corn Crushers,	Amos Glover,	Powhatan Pt.,	Ohio,	20
Ploughs,	H. H. Robertson,	Kingston,	Mo.	27

RE-ISSUES.

Air Engines, (2 patents,)	Stephen Wilcox, Jr.,	Westerly,	R. I.	20
Caoutchouc,—Preparing (2 pat's)	Charles Goodyear,	New Haven,	Conn.	20
Carpet Sweeper	H. H. Herrick,	E. Boston,	Mass.	20
Glass,—Manufacture of Flint	Horace Trumbull,	Jersey City,	N. J.	20

Harvesters,	S. W. Tyler,	Greenwich,	N. Y.	13
Hemp Cutters,	Smith & Hardeman,	Springfield,	Ohio,	23
Lubricating Compound,	J. B. McMunn,	Port Jervis,	N. J.	20
Photographic Baths,	Bernard Hufnagel,	City of	N. Y.	13
Sewing Machines,	R. M. Berry,	"	"	13
Skates,	Wm. Scarlett,	Aurora,	Ill.	13
Stones,—Raising, &c.,	Solomon E. Bolles,	Mattapoisett,	Mass.	6
Stoves,—Coal	Eddy & Shavor,	Troy,	N. Y.	13
Valve Cocks,—Action of (2 pat's)	F. H. Bartholomew,	City of	"	13

DESIGNS.

Drawer Pull,	Sargent & Bradford,	New Britain,	Conn.	13
Spoons, Forks, &c.,—Handles of	John Polhamus,	City of	N. Y.	13
Stove,	Steffe & Sailor,	Philadelphia,	Penna.	13
—— Doors,	J. D. Marshbank,	Lancaster,	"	13
Stoves,—Parlor Cooking	N. S. Vedder,	Troy,	N. Y.	13
Stove Plates,—Cooks	"	"	"	13
Tea Service,	H. G. Reed,	Taunton,	Mass.	13
Theodore Parker,—Medallion	T. A. Carew,	Cambridge,	"	13

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, January 17, 1861.

John C. Cresson, President, in the chair.

Isaac B. Garrigues, Recording Secretary.

John F. Frazer, Treasurer.

The minutes of the last meeting were read and approved.

A letter was read from Prof. Dr. Johannes Gistel, of Ratisbonne, Bavaria.

Donations to the Library were received from the Royal Society, London; l'Ecole des Mines, Paris, and la Société Industrielle de Mulhouse, France; the Lower Austrian Mechanics Institute, and the Royal Imperial Geological Association, Vienna, Austria; Prof. Dr. J. Gistel, Ratisbonne, Bavaria; Messrs. Munn & Co., City of New York; Frederick Emmerick, Esq., Washington, D. C.; B. H. Latrobe, Esq., Baltimore, Md.; and Prof. John F. Frazer, Philadelphia.

Donation to the Cabinet from Marine T. W. Chandler, Esq., Engineer of the Don Pedro II. Railroad—specimens of Brazilian Woods.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer read his statement of the receipts and payments for the month of December, and his annual statement for 1860.

The annual report of the Committee on Publications, of the state of the Journal for 1860, was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (5) were proposed, and the candidates proposed at the last meeting (6) duly elected.

The Tellers of the Annual Election for Officers, Managers, and Audi-

tors, for the ensuing year, reported the result, when the President declared the following gentlemen duly elected:—

John C. Cresson, President.

John Agnew, Matthias W. Baldwin, } Vice Presidents.

Isaac B. Garrigues, Recording Secretary.

Frederick Fraley, Corresponding Secretary.

John F. Frazer, Treasurer.

MANAGERS.

Samuel V. Merrick,	Thomas J. Weygandt,	Washington Jones,
Thomas Fletcher,	George Erety,	William Harris,
Edwin Greble,	Evans Rogers,	John E. Wootten,
Thomas S. Stewart,	Robert Cornelius,	Joseph Hutchinson,
Alan Wood,	William Sellers,	Joseph W. Moore,
John E. Addicks,	James H. Bryson,	John R. Whitney,
Isaac S. Williams,	John M. Gries,	William A. Drown,
George W. Conarroe,	James Dougherty,	James S. Mason.

AUDITORS.

Samuel Mason, James H. Cresson, William Biddle.

At a meeting of the Board of Managers, held January 23d, 1861, the following officers were elected for the ensuing year:

James H. Bryson, Chairman.

Isaac S. Williams, John M. Gries, } Curators.

Mr. C. E. H. Richardson exhibited his patent "Air and Damp-tight Burial Caskets." The shells are composed of ornamental wood; the sides are parallel and the ends semicircular. The top is closed first by a glass plate fitted into a hinged frame, which, when shut down, is covered by a tight lid of wood of the same kind as the shells. The exterior is furnished with the appropriate ornaments. The interior is coated with three applications of the deutoxide of manganese, over which is placed a lining of cork wood, of suitable thickness, prepared with a mixture of collodion and shellac dissolved in benzole. The inside is then lined with satin, or other material usually employed.

The construction is such that air and moisture are excluded, and decomposition of the contained body arrested. They have a handsome appearance, and are recommended by Mr. Barker of Mount Auburn Cemetery, Professor J. Wyman of Harvard University, Professor Jackson, State Assayer of Massachusetts, and others. They have received premiums from the Maryland Institute, and the Mechanics Association of Massachusetts.

Mr. Howson exhibited a Bombshell invented by Wm. Rice, Esq., of this city, and patented in this country and in Europe. The shell is intended to take the place of the *Scharpnell* shell, which consists of a number of spherical balls deposited in a cast iron case, sulphur being poured in to solidify the mass, after which a hole is drilled to make a chamber for the powder. Mr. Rice's shell consists of a number of pieces of cast iron, dovetailed or wedged together, and so

arranged that there is a central compartment for the reception of the powder. The mass of cast iron pieces is formed into a core, around which the shell is cast.

Mr. H. also exhibited a specimen of a Lamp Cap for burning coal oil, the manufacture of J. C. Vankirk & Co., of Frankford, Pa., and pointed out the improvement, which consists of a bolt pressed forward by a spiral spring which takes the place of the ordinary set-screw, and which allows the glass chimney to expand, and yet retains it firmly in its position, thus preventing the breaking of the glass, which often occurs with the ordinary set-screws.

A peculiar construction of Wagon, made by Mr. Smith, of Sullivan County, Pa., was exhibited by Mr. H.; the peculiarity consisting in the entire structure being made of wood. Mr. H. remarked that it seemed almost impossible that a wagon should hold together under such circumstances, but that he had been credibly informed that such was the case. The model attracted much attention.

A specimen of Lamp-stand was also exhibited, which consisted of a simple stem of cast iron, the glass reservoir being attached by means of plaster of paris.

A new Broom, composed of Brazilian Piassaba surrounded by broom-corn, was exhibited by Mr. H. The piassaba plant is very elastic and durable, and has a tendency to penetrate the interstices of the carpet, but owing to its yielding qualities it cannot be made into an efficient broom. By surrounding it with broom-corn, the piassaba is maintained in a comparatively solid mass, and forms with the broom-corn, a most efficient broom.

Mr. H. also exhibited a Gas-burning Stove, the invention of J. L. Mahan, Esq., of this city, and manufactured by Messrs. Stuart & Peterson. The peculiarity of this stove consists in having a plain surface of metal on a level, or thereabouts, with the wire gauze through which the gas passes; the flame, coming in contact with this level surface, heats the air contained in the chamber beneath, and this heated air passes upwards and furnishes that plentiful supply of oxygen which destroys the noxious vapors generated in other gas stoves. The stove was tried in the presence of the meeting, and the President remarked that although some noxious vapors arose from it, it was the best specimen of a gas stove he had seen.

COMMITTEE ON SCIENCE AND THE ARTS.

Report on Robert McWilliams's Improved Axle Box.

The Committee on Science and the Arts constituted by the Franklin Institute of the State of Pennsylvania, for the promotion of the Mechanic Arts, to whom was referred for examination—"An improved Axle box," invented by Robert McWilliams and assigned to Samuel W. Hoffman,

REPORT:—That they have examined the model of this box, the inventor of which claims that it possesses two peculiarities,—first, that

the lower half of the box is so arranged that it can be detached to be filled with waste and oil in such a manner that upon returning it to its place no oil will be spilled nor the waste disturbed; secondly, that a very simple movable washer is provided at the back of the box which moves up with the journal as the brass wears and keeps the joint always tight and impervious to dust.

The first peculiarity renders the box convenient in oiling and filling, particularly since it permits free access to the journal, one-half of which is entirely exposed.

On the whole, the Committee consider that the arrangement is a simple and ingenious one, and that it is well adapted to fulfil the purpose for which it is intended. As far as the Committee know it is new. The drawings and model accompanying this report will fully explain it.

By order of the Committee,

WM. HAMILTON, *Actuary.*

Philadelphia, March 8th, 1860.

Description by the Inventor.

Fig. 1 is a side view of the axle box, illustrating the method of connecting and disconnecting the lower half of the same.

Fig. 2, a sectional elevation of the box.

Fig. 3, a transverse section on the line 1, 2, Fig. 2, looking in the direction of the arrow 1.

Fig. 4, a transverse section on the same line, but looking in the direction of the arrow 2; the lower half of the box being removed in this view.

Fig. 5, a sectional plan on the line 3, 4, Fig. 2.

Similar letters refer to similar parts throughout the several views.

A is the upper half, and B the lower detachable half of the axle-box. The upper half, A, has on each side the usual lugs, *a a*, which serve to guide the box during its vertical movement in a hanger of the ordinary construction. C is the brass-bearing, fitting snugly in a recess in the upper half, A, of the box, and maintained in its proper position in front by a lip, *b*, and at the back by a lip, *c*. In front of the upper half, A, of the box, and forming part of the same, are two projections, *d d*, the object of which will be rendered apparent hereafter. In the rear of the box is an opening, *e*, for the admission of the axle, D; the said opening being elongated vertically, in order that the box may be raised to a sufficient height to allow the brass-bearing, C, to be removed and replaced by passing it between the collar, *f*, on the end of the axle and the retaining lip, *b*.

It will be observed, on reference to Fig. 4, that the vertical portion of the upper half, A, of the box, has a flanch, *h*, extending down each side and transversely across the bottom,—thus forming a recess, or socket, for the reception of the end of the oil-box, which forms a part of the lower half, B, of the box. Within the recess formed by the

flanch, *h*, is another recess, for the reception of the leather strip, E, and the metal plate, F,—this recess extending upwards to within a short distance from the top of the box, as seen in Fig. 2.

Fig. 1

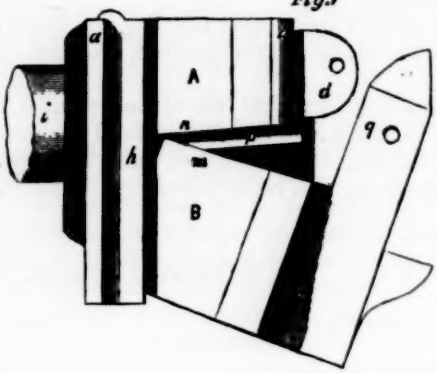


Fig. 3

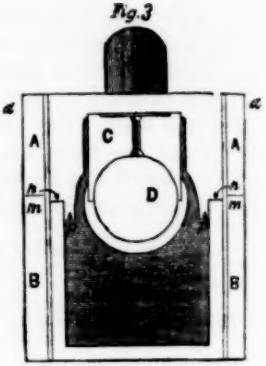


Fig. 2

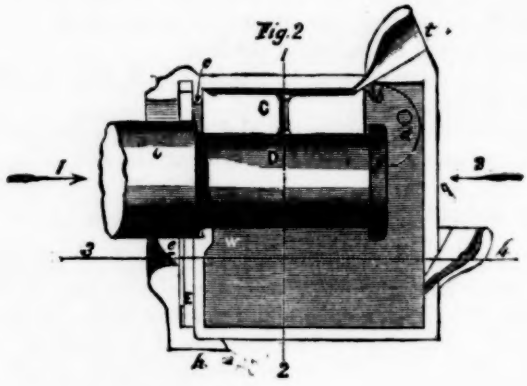


Fig. 4

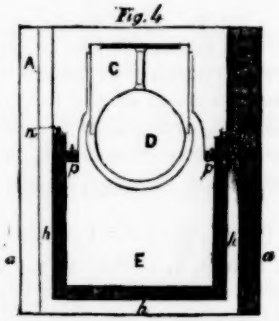
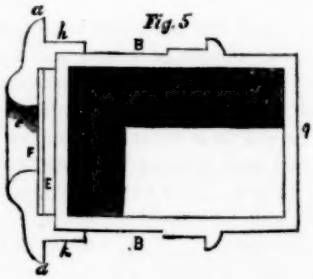


Fig. 5



The enlarged portion, *i*, of the axle, D, passes through and fits snug-

ly, but so as to move freely in circular openings, both in the leather strip and iron plate.

It will be seen, on reference to Fig. 2, that the recess for the reception of the leather strip is somewhat longer than the strip itself, thus enabling the latter to rise with the shaft as the brass-bearing wears.

The lower half, B, of the box, the greater portion of which forms the oil-chamber, fits snugly with its end into the socket formed by the flanch, *h*, of the upper half of the box. The upper edges, *m*, of the oil-chamber fit to the inclined shoulders, *n*, on the upper half of the box, a flanch, *p*, projecting from each shoulder a short distance into the inside of the oil-chamber. The vertically projecting portion, *q*, of the lower half of the box, is a continuation of the oil-chamber, and fits snugly over the projections, *d*, of the upper half of the box, a simple bolt passed through this portion, *q*, and through the projections, *d*, being all that is necessary to secure the two halves of the box together. Oil is furnished to the journal through an orifice in a projection, *t*, communicating with a passage in the upper half of the box, through which the oil flows into a channel cut into the top of the brass-bearing, and thence through an opening in the latter to the journal of the axle. The lower oil receiver being on a line parallel with the end, *w*, of the oil-chamber, is also a gauge for the oil.

It will be observed that the point of junction of the edge, *m*, of the lower half, with the edge, *n*, of the upper half of the box, is in a line above the lower line of the journal. In this respect my present improvement is similar to that invented by me, and described in the patent granted to me and Adam J. Frederick, on the 15th day of December, 1857.

In the axle-box described in that patent, however, permanent grooves were formed on each side of the upper half of the box above the line of junction with the lower half, longitudinal projections being formed on the latter to fit into the grooves, so that on adjusting the lower half to the upper half of the box it was necessary to maintain the former in nearly a horizontal position while it was being slided on to the upper half.

There are two serious objections to this mode of securing the two halves together. First, it is necessary that the end of the oil-chamber should be hollowed out sufficiently to escape the outer collar of the journal on sliding the lower half of the box to its place, so that when adjusted the hollow upper edge of the end of the oil-box is so far below the journal that the main body of oil contained in the box is always accessible to the leather packing, and consequently readily finds its way between the latter and the axle; the result being, of course, a great waste of oil.

The second and no less serious objection is, that in sliding the lower half of the box horizontally, or nearly so, so as to fit to the upper half of the box, the outer collar of the axle bears against the cotton packing contained in the oil-chamber, and forces it to the front of the latter, so that the rear part of the journal is free from contact with the said packing, and is, therefore, insufficiently lubricated.

My present improvement has been especially designed to obviate the foregoing objectionable features.

By the peculiar construction of the upper and lower half of the box, the latter, in being adjusted to the frame, is depressed in front, as seen in fig. 1, the end of the oil-chamber resting on the bottom flanch, *h*, of the socket of the upper half of the box. The outer end of the lower half of the box is then gradually raised, and at the same time pressed forward, until the edge, *n*, of the upper half coincides with the edge, *m*, of the lower half, and the projections, *d*, fit into the vertical portion, *q*, of the lower half of the box.

By this arrangement, the end, *w*, of the oil-chamber may be hollowed out to an extent just sufficient to fit snugly to the bearing of the axle, thus excluding the main body of the oil from contact with the leather packing, as seen in fig. 2.

It will also be seen that by this method of adjusting the lower to the upper half of the box, the saturated packing remains undisturbed, and distributes the oil evenly throughout the entire surface of the journal.

The leather strip, E, (which is one piece,) and the plate, F, are retained in their proper position against the end of the box by the end of the oil-chamber, as best observed on reference to fig. 2. As sufficient room is left for the leather strip to rise in its recess as the brass-bearing becomes worn, it is evident that it will adjust itself to the position of the axle, and continue to act as a means of preventing the escape of oil, no matter what may be the extent of the wear of the bearing. The only object of the plate, F, is to prevent the leather strip from bulging outwards into the elongated opening, *e*.

I do not claim broadly making the box in two halves, and so arranging the same that the point of junction shall be above the lower line of the bearing, as this arrangement is covered by the patent granted to me and A. J. Frederick on the 15th day of December, 1857,—the aforesaid S. W. Hoffman being Assignee for the same.

METEOROLOGY.

For the Journal of the Franklin Institute.

The Meteorology of Philadelphia. By JAMES A. KIRKPATRICK, A.M.

DECEMBER.—The month of December, 1860, was colder than usual, the temperature being nearly one degree below that of December, 1859, and nearly three degrees below the average temperature of the month for ten years. It was also more equable, the mean daily range being but five degrees, while it is usually about six and a half, and during December, 1859, it was nearly eight and a half degrees.

The Schuylkill river was open to navigation below the dam, during the whole month; it was closed above the dam for two days only.

The warmest day of the month was the 20th, which had a mean temperature of 42·7°. In the afternoon of the same day the thermometer attained its maximum of 50°.

The 15th was the coldest day, the mean temperature being 17·3°. The minimum (13½°) occurred on the same day; making the monthly range of temperature 36½°.

The temperature was below the freezing point on 24 days of the month, though it rose above that point in the course of the afternoon every day except two, namely, the 14th and 15th.

The barometric pressure was greatest on the evening of the 14th, when the mercury stood at 30·418 inches; but the average pressure for the day was greatest on the 29th, the mean for that day being 30·345 inches, while for the 14th it was but 30·300.

The barometric pressure was least on the 20th of the month, falling as low as 29·285 inches during a heavy fog. The average pressure for the day was 29·356 inches.

Rain fell on four and snow on five days. The amount of rain and melted snow (3·301) was the least amount for December since the year 1854, when only 3·185 inches fell.

There were seven days on which the sky was entirely covered with clouds, and only two which were clear or free from clouds at the hours of observation.

TABLE I.—*A Comparison of some of the Meteorological Phenomena of* DECEMBER, 1860, *with those of December*, 1859, *and of the same month for ten years, at Philadelphia.*

	Dec., 1860.	Dec., 1859.	Dec., 10 years.
Thermometer.—Highest,	50°	71°	71°
" Lowest,	13·5	9	4·5
" Daily oscillation,	12·2	14·2	12·0
" Mean daily range,	5·0	8·4	6·4
" Means at 7 A. M.,	29·32	30·66	31·65
" " 2 P. M.,	35·65	36·48	38·91
" " 9 P. M.,	31·82	31·87	34·44
" " for the month,	32·26	33·00	35·00
Barometer.—Highest,	30·418 in.	30·293 in.	30·678 in.
" Lowest,	29·285	29·393	28·946
" Mean daily range,	·196	·199	·212
" Means at 7 A. M.,	29·937	29·941	29·953
" " 2 P. M.,	29·911	29·906	29·916
" " 9 P. M.,	29·958	29·930	29 939
" " for the month,	29·936	29·926	29·936
Force of Vapor.—Means at 7 A. M.,	·132 in.	·148 in.	·141 in.
" " " 2 P. M.,	·140	·171	·168
" " " 9 P. M.,	·134	·158	·153
Relative Humidity.—Means at 7 A. M.,	79 per ct.	76 per ct.	77 per ct.
" " " 2 P. M.,	66	69	67
" " " 9 P. M.,	73	77	75
Rain and melted snow,	3·301 in.	3·460 in.	3·876 in.
No. of days on which rain or snow fell,	8	10	11
Prevailing winds,	N.51°45′W·411	N.37°45′W·229	N.53°45′W·281

TABLE II.—*A General Abstract of the Meteorological Observations made at Philadelphia during the year* 1860.
Latitude, 39° 57′ 28″ N. Longitude, 75° 10′ 28″ W. from Greenwich. Height of Barometer fount, fifty feet above mean tide.

1860. MONTHS.	Barometer, reduced to 32° F.								Thermometer.								Dew Point at 2 P. M.			
			Range.		Means.						Range.			Means.						
	Highest.	Lowest.	Monthly.	Mean daily.	7 A. M.	2 P. M.	9 P. M.	Monthly.	Maximum.	Minimum.	Monthly.	Mean daily.	Mean daily oscillation.	7 A. M.	2 P. M.	9 P. M.	Monthly.	Maximum.	Minimum.	Range.	Mean.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	°	°	°	°	°	°	°	°	°	°	°	°	°
January,	30·399	29·593	·806	·159	29·970	29·915	29 938	29·941	58	3½	54½	6·5	14·8	28·89	38·37	32 97	33·41	45 8	5·4	40·4	24·99
February,	30·358	29·099	1·259	·209	29.970	29 885	29·918	29 924	70	1	69	8·8	17·8	27·24	38·07	31·69	32·33	54·0	—3 9	57·9	24·42
March,	30·224	29·499	·725	·133	29·829	29·757	29·795	29·794	73	25	48	5·4	18 3	38·15	52·34	43 71	44·73	58 9	10·4	48·5	28 62
April,	30·303	29·319	·984	·166	29·849	29 794	29·830	29·824	81	29	52	7·4	18·9	43·96	56·56	47·92	49·48	59·0	13 8	45·2	35·91
May,	30·050	29·479	·571	·100	29·828	29·787	29·815	29 810	90	44	46	5·2	17·2	59·66	71·03	61·57	64 09	63·9	37 4	26·5	53 54
June,	30·123	29 243	·880	088	29·757	29 719	29·745	29·740	93	52	41	4·2	18·9	67·70	78·38	69·05	71·71	71·7	38·6	33·1	56 07
July,	29·979	29·495	·484	·112	29 811	29·774	29·787	29·791	95½	57	38½	5·0	19 8	72 50	83·89	74·34	76 91	70·9	44·0	26·9	58·29
August,	30·026	29·632	·394	·090	29·848	29·813	29·834	29·832	95	55	40	3·8	18 8	70·13	82·87	73·29	75·43	74·4	42 7	31·7	62·57
September,	30·313	29 597	·716	·143	30 003	29·965	29·998	29·989	92	42	50	5·2	18·2	60·28	73·17	64 02	65·82	73·4	29·2	44·2	53·14
October,	30·275	29·312	963	·119	29·963	29·906	29 938	29·936	79	36	43	5·8	16·1	51·58	63·29	55·61	56·83	66·0	32 8	33·2	48·64
November,	30·305	29·248	1·057	·197	29 821	29·773	29·792	29·795	80	16	64	5·5	14·4	43 30	50·53	45·33	46·39	62·2	12·4	49 8	35·21
December,	30 418	29·285	1·133	·196	29·937	29·911	29 958	29·936	50	13½	36½	5·0	12·2	29 32	35·65	31 82	32·26	38·5	5·6	32·9	24 99
Annual means,	30·418	29·099	1·319	·143	29·882	29·833	29·862	29·859	95½	1	94½	5 6	17·1	49·39	60·35	52·61	54·12	74·4	—3·9	78·3	42·19
Winter,	30·399	29 099	1·300	·189	29·960	29 902	29 929	29·930	71	1	70	7 9	15·6	28·93	37·64	32·18	32·91	61·7	—3·9	65·6	25·55
Spring,	30·303	29·319	·984	·133	29·835	29·779	29·813	29·909	90	25	65	6 0	18·1	47·26	59·98	51·07	52·77	63·9	10·4	53·5	39·36
Summer,	30·123	29·243	·880	·097	29·805	29 769	29·789	29·788	95½	52	43½	4·3	19·2	70·11	81·71	72·23	74 68	74·4	38·6	35·8	58·98
Autumn,	30·313	29·248	1·065	·153	29·929	29 881	29·909	29·906	92	16	76	5·5	16·2	51·72	62·33	54·99	56·35	73·4	12·4	61·0	45·66
Means for 9 years,	30·704	28·884	1·820	·154	29·893	29·854	29·877	29·875	100½	—5½	106	5·6	15 0	49·69	59·98	53·19	54·29	79·7	—16·5	96·2	43·74

TABLE II (*Continued*).—*A General Abstract of the Meteorological Observations made at Philadelphia during the year* 1860.

TABLE II (*Continued*).—*A General Abstract of the Meteorological Observations made at Philadelphia during the year* 1860.

1860. MONTHS.	Force of Vapor.							Relative Humidity.							Clouds. Sky covered.				Rain and melt'd snow.		Winds.	
	Maximum.	Minimum.	Range.	Means.				Maximum.	Minimum.	Range.	Means.				Means.				Amount.	No. of days it fell.	Monthly resultant.	No. of times in 1000.
				7 A. M.	2 P. M.	9 P. M.	Monthly.				7 A. M.	2 P. M.	9 P. M.	Monthly.	7 A. M.	2 P. M.	9 P. M.	Mon'ly				
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Pr ct.	Pr ct.	P ct.	Per ct.	Per ct.	Per ct.	Per ct.					Inch.		Direction.	
January,	·308	·040	·268	·136	·144	·143	·141	95	24	71	79·9	60·8	73·4	71·4	·66	·64	·51	·60	3·351	7	N 89° 9′ W	402
February,	·434	·024	·410	·124	·154	·150	·143	100	35	65	74·1	58·7	71·9	68·2	·53	·49	·44	·49	2·724	7	N 61 52 W	298
March,	·497	·064	·433	·171	·175	·182	·176	97	16	81	71·4	44·3	61·5	59·1	·61	·55	·40	·52	1 323	8	N 79 17 W	224
April,	·500	·081	·419	·210	·234	·230	·225	100	21	79	70·1	50·3	67·1	62·5	·52	·59	·52	·54	3·646	15	N 88 36 W	250
May,	·638	·224	·414	·395	·421	·420	·412	94	28	66	76·2	56·7	75·6	69·5	·75	·67	·65	·69	3·589	19	N 59 2 E	70
June,	·804	·211	·593	·467	·464	·480	·470	94	26	68	68·1	48·4	66·7	61·1	·59	·57	·33	·50	3·706	10	N 67 23 W	236
July,	·783	·288	·495	·539	·505	·559	·534	90	29	61	66·5	43·4	65·3	58·4	·52	·59	·40	·50	0·851	10	S 70 1 W	135
August,	·850	·275	·575	·580	·584	·603	·589	94	27	67	77·5	52·1	73·0	67·5	·53	·57	·48	·53	9·260	13	N 80 54 W	150
September,	·822	·161	·661	·425	·437	·455	·439	93	35	58	77·1	50 4	72·1	66·5	·62	·50	·35	·49	2·907	7	S 74 26 W	397
October,	·639	·172	·467	·321	·363	·354	·346	95	41	54	80·4	60·6	77·4	72·8	·64	·62	·50	·59	4·685	13	S 75 58 W	69
November,	·568	·058	·510	·234	·228	·236	.233	93	35	58	76·2	57·0	71·4	68·2	·64	·61	·48	·58	6·057	12	N 81 25 W	333
December,	·275	·056	·219	·132	·140	·134	·135	92	38	54	78·9	65·8	72·7	72·5	·64	·69	·48	·60	3·301	8	N 51 45 W	411
Annual means,	·850	·024	·826	·311	·321	·329	·320	100	16	84	74·7	54·0	70·7	66 5	·60	·59	·46	·55	45·400	129	N 79 43 W	219
Winter,	·551	·024	·527	·136	·156	·150	·147	100	24	76	76·8	63·0	74 2	71·3	·63	·63	·48	·58	9·535	24	N 67 50 W	289
Spring,	·638	·064	·574	·259	·277	·277	·271	100	16	84	72·6	50·4	68·1	63·7	·63	·60	·52	·58	8·558	42	N 76 26 W	119
Summer,	·850	·211	·639	·529	·518	·547	·531	94	26	68	70·7	48·0	68·3	62·3	·55	·58	·40	51	13·817	33	N 82 27 W	165
Autumn,	·822	·058	·764	·327	·343	·348	·339	95	35	60	77·9	56·0	73·6	69·2	·63	·58	·44	·55	13·649	32	S 84 34 W	254
Means for 9 years,	1·059	·013	1·046	·327	·345	·347	·340	100	13	87	76·4	57·9	72·5	68·9	·59	·59	·44	·54	44·692	126	N 74° 51′ W	215

THE YEAR 1860.—The temperature of the year was about two-tenths of a degree below the average temperature for nine years. The coldest day was the 2d of February, of which the mean temperature was 9·2°, and the minimum (1°) was reached on the same day.

The warmest day was the 20th of July, of which the mean temperature was 87·7°, and the thermometer marked the highest degree (95½°) on the same day.

The greatest barometric pressure was 30·418 inches on the 14th of December, and the least, 29·099 inches, on the 18th of February.

The Delaware river was not closed with ice during the whole year; it has not been closed to navigation since the beginning of March, 1858. The Schuylkill was closed for about two weeks in the beginning of January, 1860.

Table II. contains a general abstract of the observations made during the year; the barometric observations being corrected for temperature, but not for altitude; the barometer fount being fifty feet above mean tide in the Delaware river.

Table III. contains a comparison, in the usual form, of the year 1860 with 1859, and with the average results for nine years.

TABLE III.—*A Comparison of some of the Meteorological Phenomena of the year* 1860, *with those of* 1859, *and of the last nine years, at Philadelphia.*

	1860.	1859.	Nine years.
Thermometer.—Highest,	*a* 95·5°	*e* 97°	*i* 100.5°
" Lowest,	*b* 1·0	*f*—2	*j*—5·5
" Daily oscillation,	17·12	17·20	14·99
" Mean daily range,	5·65	6·00	5·62
" Means at 7 A. M.,	49·39	49·93	49·69
" " 2 P. M.,	60·35	60·53	59·98
" " 9 P. M.,	52·61	53·00	53·19
" " for the year,	54·12	54·49	54·29
Barometer.—Highest,	*c* 30·418 in.	*g* 30·475 in.	*k* 30·704 in.
" Lowest,	*d* 29·099	*h* 28·890	*l* 28·884
" Mean daily range,	·143	·158	·154
" Means at 7 A. M.,	29·882	29·881	29·893
" " 2 P. M.,	29·833	29·840	29·854
" " 9 P. M.,	29·862	29·867	29·877
" " for the year,	29·859	29·863	29·875
Force of Vapor.—Means at 7 A. M.,	·311 in	·313 in.	·327 in.
" " " 2 P. M.,	·321	·331	·345
" " " 9 P. M.,	·329	·332	·347
Relative Humidity.—Means at 7 A. M.,	75 per ct.	75 per ct.	76 per ct.
" " " 2 P. M.,	54	56	58
" " " 9 P. M.,	71	71	73
Rain and melted snow,	45·400 in.	54·752 in.	44.692 in.
No. of days on which rain or snow fell,	129 days.	127 days.	126 days.
Prevailing winds,	s.79°43′w·219	s.79°31′w·255	s.74°51′w·215

a July 20. *b* February 2. *c* December 14. *d* February 18. *e* July 13 and August 4. *f* January 10. *g* January 24. *h* April 23. *i* 1854, July 21. *j* 1857, January 23. *k* 1853, January 28. *l* 1852, April 21.

Abstract of Meteorological Observations for November, 1860; made in Philadelphia, Franklin, and Somerset Counties,

Abstract of Meteorological Observations for November, 1860; made in Philadelphia, Franklin, and Somerset Counties, Pennsylvania, for the Committee on Meteorology of the Franklin Institute.

1860.	Philadelphia.—Lat. 39° 57′ 28″ N. Long. 75° 10′ 28″ W. Height above the sea 50 feet. Prof. J. A. Kirkpatrick, Observer.									Chambersburg, Franklin Co. Lat. 39° 58′ N. Long. 77° 45′ W. Height 618 ft. Wm. Heyser, Jr., Observer.									Somerset, Somerset Co. Lat. 40° N. Long. 79° 3′ W. Height 2195 feet. Geo. Mowry, Observer.								
	Barometer.		Thermometer.			Force of vapor.	Relative humidity.	Rain and snow.	Prevail'g winds.	Barom.	Thermom.		Force of vapor.	Relative humidity.	Rain and snow.	Prevail'g winds.			Barom.	Thermom.		Force of vapor.	Relative humidity.	Rain and snow.	Prevail'g winds.				
Nov.	Mean.	Mean daily range	Mean.	Daily oscillation.	Mean daily range.	2 P.M.	2 P.M.			Mean.	Mean.	Mean daily range.	2 P.M.	2 P.M.					Mean.	Mean.	Mean daily range.	2 P.M.	2 P.M					
	Inch.	Inch.	°	°	°	Inch.	Per ct.	Inches.	Direc.	Inch.	°	°	Inch.	Per ct	Inch.	Direc.			Inch.	°	°	Inch.	Per ct.	Inch.	Direc.			
1	30·069	·056	69·0	18	1·7	·560	60	0·016	S E.	29·404	67·7	0·7	·658	99	}	(var.)			27·761	62·0	1·0	·475	69					E S E.
2	30·067	·018	67·2	14	2·2	·524	65	0·025	E S E.	29·348	68·0	0·3	·572	75	} 1·860	E.			27·698	60·7	2·0	·490	81	} 2·192				E.
3	29·628	·439	62·5	7	5·0	·507	91	2·998	N E.	29·057	62·7	8·7	·452	94	}	(var.)			27·538	51·3	8·7	·295	73					W.
4	29·812	·245	51·8	15	10·7	·187	41		W.	29·211	47·3	12·0	·183	49		W.			27·614	40·3	11·0	·185	58					W.
5	29·825	·103	54·0	22	7·2	·224	40		S W.	29·142	50·7	7·3	·269	54		(var.)			27·545	46·7	6·3	·242	52					(var.)
☾ 6	29·796	·088	47·2	13	7·8	·142	35		W N W	29·208	48·3	2·7	·020	41		W.			27·611	35·3	11·3	·103	45					W.
7	29·991	·195	43·3	16	3·8	·135	37		W N W	29·387	41·3	7·3	·121	36		W.			27·749	35·0	2·3	·125	49					W N W.
8	30·023	·058	43·8	16	1·8	·188	51		N W.	29·416	43·3	2·0	·189	56		S E.			27·746	40·7	9·7	·220	59					N.
9	29·866	·157	45·5	9	3·0	·203	59	0·098	(var.)	29·138	45·7	4·3	·249	77	} 1·215	S E.			27·489	42·7	6·7	·283	85	1·181				E.
10	29·285	·581	49·0	11	4·5	·199	62	0·009	S S W.	28·751	45·7	3·3	·177	66	}	W.			27·219	34·3	8·3	·162	84	} 0·246				W.
11	29·517	·231	40·2	6	3·5	·206	66	0·003	N W.	28·969	48·0	4·3	·209	58		W.			27·450	37·3	3·7	·175	69					W.
● 12	29·581	·065	47·3	14	2·5	·255	66		N W.	29·003	47·3	3·3	·181	43		W.			27·441	39·3	4·7	·212	63					(var.)
13	29·756	·175	47·3	9	0·0	·229	59		N W.	29·218	48·7	1·3	·192	44		W.			27·683	41·0	2·3	·212	63					N W.
14	29·910	·154	49·3	17	4·7	·212	46		N W.	29·363	46·3	4·3	·229	48		W.			27·785	39·3	3·0	·185	51					W.
15	29·964	·054	49·8	13	2·5	·240	55		N W.	29·399	47·7	3·3	·179	40		W.			27·798	38·3	3·7	·194	48					?
16	30·004	·046	49·3	16	1·2	·240	55		N W.	29·412	45·0	5·3	·194	48		(var)			27·772	41·3	3·0	268	62					S W.
17	29·781	·222	51·3	15	2·0	·292	65		N W.	29·135	47·7	4·0	·296	79	} 0·365	(var.)			27·507	45·7	5·0	·281	63					S.
18	29·404	·378	50·7	9	3·3	·266	61	0·281	(var.)	28·763	46·3	3·3	·234	65	}	(var.)			27·212	38·3	7·3	·203	82	0·021				W.
19	29·448	·045	50·5	14½	3·2	·252	56		S W.	28·734	47·3	1·0	·258	72		W.			27·158	39·7	2·0	·208	75	0·265				(var.)
☽ 20	29·615	·167	43·0	13	7·5	·139	42	0·007	W.	29·064	42·0	5·3	·121	43		W.			27·410	30·7	9·0	·128	64					W.
21	29·774	·159	38·0	12	5·0	·110	41		W S W	29·150	36·3	5·7	·131	55		W.			27·479	28·3	2·3	·175	94	0·034				(var.)
22	29·997	·223	37·0	15	1·0	·131	49		(var.)	29·364	36·3	4·0	·105	41		S W.			27·657	30·3	5·3	·129	61	0·236				(var.)
23	29·739	·258	47·7	21	10·7	·297	92	} 0·654	S E.	29·025	38·0	3·0	·194	82	0·316	N E.			27·335	38·3	8·0	·214	69	0·773				S.
24	29·667	·281	27·2	35	20·5	·087	58		W.	29·015	20·3	17·7	·076	70		W.			27 394	11·0	27·3	·056	65					W.
25	30·092	·424	23·3	13	7·2	·076	52		W S W	29·452	21·3	6·3	·061	41	0·315	W.			27·749	12 7	4·3	·081	77					W.
26	30·234	·144	33·7	18½	10·3	·087	37	0·774	(var.)	29·526	31·0	9·7	·114	61		W.			27·795	26·7	14·0	·101	55	0·770				S.
27	29·901	·333	40·3	13	15·7	·347	93	0·220	(var.)	29·260	40·0	9·0	·244	91		N E.			27·638	42·0	15·3	·298	92	0·123				W.
○ 28	29·936	·071	39·0	14	10·3	·145	56		N W.	29·300	36·7	4·3	·113	42		W.			27·675	30·7	11·3	·152	64					N W.
29	29·779	·157	37·5	15	3·8	·122	43		N W.	29·164	37·3	5·7	·186	67		(var.)			27·471	32·3	7·7	·177	66					S W.
30	29·408	·372	40·8	9	3·3	·233	79	0·072	S S W.	28·979	40·7	6·7	·125	40	0·110	(var.)			27·105	35·3	6·3	·203	82	0·253				W S W
Means	29·795	·197	46·4	14¼	5·5	·228	57	6·057	s 81½° w	29·202	44·1	5·2	·214	59	4·181	s 64½° w			27·549	37·6	7·1	·280	67	6·094				s 68½° w

Abstract of Meteorological Observations for November, 1860; made in Adams, Dauphin, Northumberland, Centre, and Erie Counties, Pennsylvania, for the Committee on Meteorology of the Franklin Institute.

	Gettysburg, Adams Co. Lat. 39° 49′ N. Long. 77° 18′ W. Ht. 624 ft. Prof. M. Jacobs, Obs.					Harrisburg, Dauphin Co. 40°16′, N. 76°50′, W. Ht., 300 ft. John Heisely, M.D., Obs.					Shamokin, Northumberland Co. 40° 45′ N. 76° 30′ W. Height, 700 ft. P. Friel, Obs.				Fleming, Centre Co. 40° 55′ N. 77° 53′ W. Ht., 780 feet. S. Brugger, Obs.				Erie, Erie Co.—Lat. 42° 8′ N. Long. 80° 12′ W. Height about 640 feet. Benjamin Grant, Obs.					
1860.	Barom	Thermom.		Rain and snow.	Prevail'g winds.	Barom	Thermom.		Rain and snow.	Prevail'g winds.	Thermom.		Rain and snow.	Prevail'g winds.	Thermom.		Rain and snow.	Prevail'g winds.	Barom	Thermom.		Force of Vapor.	Relative humidity.	Rain and snow.	Prevail'g winds.
Nov.	Mean.	Mean.	Mean daily range.			Mean.	Mean.	Mean daily range.			Mean.	Mean daily range.			Mean.	Mean daily range.			Mean.	Mean.	Mean daily range.	2 P. M.	2 P. M.		
	Inch.	°	°	Inch.	Direc.	Inch.	°	°	Inch.	Direc.	°	°	Inch.	Direc.	°	°	Inch.	Direc.	Inch.	°	°	Inch.	Per ct.	Inch.	Direc.
1	29·577	68·7	4·0	0·333	S S E.	29·925	70·7	2·7		S E.	67·3	2·3	0·151	E.	67·0	2·3	0·200	(var.)	29·362	69·0	2·3	·479	55		S W.
2	29·535	67·3	2·0	0·012	E S E.	29·902	68·0	2·7	0·672	E.	65·3	2·0	0·100	E.	65·7	2·7	0 100	S E.	29·309	61·7	11·3	·394	76	1·800	(var.)
3	29·286	60·3	7·0	0·490	(var.)	29·562	63·3	4·7		N E.	61·0	4·3	0·891	(var.)	57·0	8·7	1·300	(var.)	29·217	58·3	6·0	·281	47		S.
4	29·407	44·3	16·0		(var.)	29 704	51·0	12·3		W.	61·0	0·0		E.	40·7	16·3		N W.	29·190	49·7	8·7	·105	25		S W.
5	29·336	47·3	6·3		S W.	29·656	52·3	5·3		S W.	51·0	10·7		(var.)	47·0	12·3		W.	29·122	49·3	5·0	·159	44	0·050	W.
6	29·386	38·7	8·7		(var.)	29·691	46·0	7·0		N W.	42·0	10·3	0·050	(var.)	37·7	11·3		N W.	29·291	43·3	6·0	·153	57		W.
7	29·561	38·7	2·0		N W.	29·871	44·7	1·3		N W.	40·0	3·3		W.	36·0	2·3		N W.	29·476	41·7	4·3	·166	53		W.
8	29·638	43·7	8·0		S W.	29·933	44·7	2·0		N.	38·3	3·7		W.	38·0	7·3		W.	29·479	39·7	4·0	·180	60		(var.)
9	29·364	46·3	5·7	1·275	N N E.	29·692	46·7	2·7	1·418	N.	43·3	5·0	1·638	S E.	41·7	6·3	0·820	(var.)	29·115	46·7	6·3	·261	84	1·700	E.
10	28·948	41·3	5·0		W.	29·209	46·3	1·0		W.	44·0	2·7		W.	41·7	1·3	0·600	N W.	28·933	43·3	3·3	·250	84		N.
11	29·119	45·3	4·0		N W.	29·410	50·0	3·7		N W.	42·7	4·7	0·151	W.	46·0	4·3	0·105	N W.	29·121	48·3	5·0	·267	66	0·300	N W.
12	29·200	46·0	3·3		N W.	29·484	50·0	2·7		N.	45·7	3·0		W.	44·3	5·7		W.	29·158	44·7	3·7	·245	70		N.
13	29·421	48·0	2·0		N W.	29·688	52·0	2·0		N.	45·3	2·3		W.	46·7	2·3		(var.)	29·392	46·0	1·3	·243	65		N.
14	29·556	45·7	4·3		N W.	29·852	51·3	0·7		N.	43·3	2·0		W.	43·0	4·3		(var.)				·320	79		N.
15	29·588	44·3	1·3		W.	29·885	49·3	2·0		N.	38·3	5·7		W.	42 0	1·0		(var.)							
16	29·615	43·7	2·7		(var)	29·913	49·3	1·3		N.	43·7	5·3		W.	45·0	3·0		W.							
17	29·285	45·7	6·0	0·195	W.	29·628	51·3	2·7	0·128	N.	45·0	2·7		W.	47·0	5·3		S E.	29·135	52·0		·252	52		S.
18	28·993	46·0	3·0		(var.)	29·268	50·7	4·7		W.	47·3	6·3		(var.)	43·7	7·3		(var.)	28·816	44·0	8·0	·166	53	0·360	N.
19	28·970	45·7	1·7		S W.					S W.	45·7	3·0	0·130	(var.)	41·0	4·7		W.	28·717	42·0	2·7	·062	21		W.
20	29·329	38·0	8·3		N W.	29·499	42·0			W.	41·0	8·0		W.	35·3	5·7		N W.	29·372	39·3	3·7	·153	57		W.
21	29·365	34·0	4·0		(var.)	29·641	39·7	2·3		W.	34·0	7·0		E.	34·0	1·3		N W.	29·201	34·7	4·3	·141	69		W.
22	29·582	32·7	4·0		S W.	29·883	38·7	1·7		(var.)	34·0	6·0	0·070	W.	33·7	3·0	0·305	W.	29·335	38·0	4·0	·110	41	0·440	S W.
23	29·274	35·3	4·7	0·850	S W.	29·573	40·0	2·7	0·642	S E.	37·3	6·0	0·603	E.	36·7	3·0	0·080	S W.	29·066	39·0	3·0	·131	49		S.
24	29·292	17·3	18·0		N W.	29·535	24·3	15·7		W.	19·3	17·7		W.	14·0	22·7		N W.	29·044	11·7	27·3	·075	100		W.
25	29·703	18·3	7·0		(var.)	29·977	23·3	8·3		W.	18·3	7·0		W.	13·7	4·3		N W.	29·451	13·7	6·7	·055	53		S W.
26	29·794	29·3	7·7		W.	30·121	30·7	7·3		S E.	24·0	5·7		(var.)	26 7	13·0	0·875	W.	29·385	30·7	13·7	·154	79	0·850	S.
27	29·529	40·0	14·0	0·850	S W.	29·795	41·7	11·0	0·583	S E.	43·3	19·3	0 806	E.	42·3	15·7		W.	29·301	42·0	11·3	·126	44		W.
28	29·529	34·3	5·7		N.	29·814	37·7	4·0		N.	35·7	7·7		W.	29·7	12·7		(var.)	29·390	35·7	4·0	·081	31		W.
29	29·323	31·7	6·7		(var.)					N.	31·0	11·3		W.	29·0	12·7		W.	29·076	41·3	6·7	·148	51		S W.
30	28·893	37·3	5·7		S W.	29·196	39·0			(var.)	40·3	9·3		W.	40·3	11·3		W.	28·740	38·7	6·7	·202	82	0·170	(var.)
Means	29·380	41·5	6·0	4·005	West.	29·690	46·2	4·4	3·443	N 51°W	42·3	6·1	4·590	S 83°W	40·4	7·1	4·385	N 81°W	29·192	42·4	6·5	·191	59	5·670	S 80°W

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

MARCH, 1861.

CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

Repairs and Renewal of the Roche-Bernard Suspension Bridge. From a description given by M. Noyon, Engineer. Translated by J. Bennett.

Part Second.

(Continued from page 108.)

Rebuilding of the Platform of the Bridge.—After the fall of the platform, measures were immediately taken to provide for the travel across the Vilaine, in establishing a ferry upon the site formerly used by a barge, previous to the construction of the bridge. Nearly all the wood-work of the platform was recovered; but, excepting the beams, the principal pieces of carpentry were all injured and unfit for use; and as the shortness of the beams had contributed to the fall of the platform, it was determined to use new material.

The design of M. Lacroix, Eng., was approved by the administration, who ordered the work to be vigorously executed. Unfortunately, the proper wood could not be found in the yards of any commercial port, and as the Baltic was frozen, the work must have been deferred till the following spring, had not the marine department given permission to take all the pieces of large dimensions from the Arsenal of Brest.